2005-12

Spiral development in action: a case study of spiral development in the Global Hawk Unmanned Aerial Vehicle program

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MONTEREY, CALIFORNIA

MBA PROFESSIONAL REPORT

Spiral Development in Action:
A Case Study of Spiral Development in the Global Hawk Unmanned Aerial Vehicle Program

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December 2005

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REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.

1. AGENCY USE ONLY	**2. REPORT DATE** December 2005	**3. REPORT TYPE AND DATES COVERED** MBA Professional Report

4. TITLE AND SUBTITLE: Spiral Development in Action: A Case Study of Spiral Development in the Global Hawk Unmanned Aerial Vehicle Program	**5. FUNDING NUMBERS**
6. AUTHOR(S) Wade Henning, and Daniel Walter	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000	**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A	**10. SPONSORING / MONITORING AGENCY REPORT NUMBER**

11. SUPPLEMENTARY NOTES The views expressed in this report are those of the author(s) and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited	**12b. DISTRIBUTION CODE**

13. ABSTRACT *(maximum 200 words)*

Evolutionary Acquisition (EA) is the established acquisition strategy of choice for the Department of Defense (DoD) and spiral development (SD) is the preferred process to execute this tactic. SD is used when the end-state of a weapon system is unknown, and its purpose is to get valuable capability into warfighters' hands much more quickly than before, even if the deliverable is only a partial solution. This approach is markedly different than the traditional DoD acquisition approach that too often fielded weapon systems late, over budget and with obsolete technology. As with any DoD initiative, SD is not a panacea. The purpose of this MBA Project is to identify some of the key characteristics necessary to implement SD in government acquisitions, and to present lessons learned from a program office currently using a spiral development approach. This is accomplished through a case study of the Global Hawk Unmanned Aerial Vehicle (UAV) Program. This paper examines the Global Hawk's spiral development strategies in several key program functional areas. It discusses SD challenges, and benefits with particular attention given to successful tactics and potential pitfalls of using this acquisition approach. Finally, it derives several lessons learned applicable to any DoD program manager.

14. SUBJECT TERMS Evolutionary Acquisition, Spiral Development, Agile Acquisition, Global Hawk, Unmanned Aerial Vehicle, Planning Programming Budgeting and Execution, Configuration Management, Advanced Concept Technology Demonstration, Concurrency	**15. NUMBER OF PAGES** 87
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	UL

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SPIRAL DEVELOPMENT IN ACTION: A CASE STUDY OF SPIRAL DEVELOPMENT IN THE GLOBAL HAWK UNMANNED AERIAL VEHICLE

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Submitted in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

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LIST OF ACRONYMS AND ABBREVIATIONS

ACC	Air Combat Command
ACTD	Advanced Concept Technology Demonstration
ADSI	Air Defense Situation Integrator
AFI	Air Force Instruction
AFMC	Air Force Materiel Command
BIT	Built In Test
CASE	Computer Aided Software Engineering
CBM	Condition Based Maintenance
CCB	Configuration Control Board
DAG	Defense Acquisition Guidebook
DoD	Department of Defense
DD	Degree of Difficulty
EA	Evolutionary Acquisition
EO/IR	Electro-Optical/Infrared
GAO	General Accountability Office
GHSG	Global Hawk Systems Group
GWOT	Global War on Terrorism
HALE	High Altitude, Long Endurance
ILS	Integrated Logistics Support
IPT	Integrated Product Team
ISR	Intelligence, Surveillance and Reconnaissance
KPP	Key Performance Parameter
LCC	Life Cycle Cost
LRE	Launch and Recovery Element
MCE	Mission Control Element
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
IMINT	Imagery Intelligence

OSD	Office of the Secretary of Defense
P3I	Pre-planned Product Improvements
PM	Program Manager
POM	Program Objective Memorandum
PPBES	Planning Programming Budgeting and Execution System
RCM	Reliability Centered Maintenance
RDT&E	Research Development Test and Evaluation (appropriation)
RWG	Requirements Working Group
SAR	Synthetic Aperture Radar
SD	Spiral Development
SDIPT	Spiral Development Integrated Product Team
SIMS	Secure Instant Messaging System
SIGINT	Signals Intelligence
SIPRNET	Secret Internet Protocol Router Network
TOC	Total Ownership Cost
TPM	Technical Performance Measure
TPRI	Technology Performance Risk Index
UAV	Unmanned Aerial Vehicle

ACKNOWLEDGMENTS

We would like to thank Dr. Aruna Apte and Dr. Rene Rendon for their interest, expertise, and direction to help us accomplish this MBA Professional Report. In addition, we appreciate the time and knowledge granted to us through many interviews by several key members of the Global Hawk Systems Group at Wright Patterson Air Force Base, Ohio. Finally, we offer our thanks to our spouses for their understanding and support in this endeavor.

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I. INTRODUCTION

1.1 BACKGROUND

Evolutionary Acquisition (EA) has been named the acquisition strategy of choice for the Department of Defense (DoD) and spiral development (SD) is the preferred process to execute this strategy.[1] There have been a small number of programs that have been under spiral development for any length of time, since SD was only conceived in the 1980s[2], and the DoD has only embraced the process over the past five years. One of these pathfinder programs is the Global Hawk UAV program, which is managed by the Global Hawk Systems Group (GHSG), within the Reconnaissance Systems Wing, located at the Aeronautical Systems Center, Wright Patterson Air Force Base, Ohio. The Global Hawk program is known as a trailblazer in the area of spiral development, and can offer priceless insight into some of their lessons learned.

Implementing an appropriate spiral development strategy is easier said than done. In fact, there have been many challenges in implementation. As more programs evaluate the feasibility of spiral development, they will need a practitioner's view to help them institute the new process. This project should assist the practitioner in this endeavor. It will also give background on key programmatic areas that Integrated Product Team (IPT) members must focus on to help achieve spiral development success.

Most program offices have specialized managers in each of their areas of expertise, therefore we have tailored research questions to benefit each practitioner. This paper should benefit personnel in the technical, financial management, and logistics arenas, as well as program managers of potential spiral development programs.

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1 US Department of Defense. (2003, May) "The Defense Acquisition System." DoD Directive 5000.1. p. 2.

2 Blanchard B. S. & Fabrycky, W. J. (1998) *Systems Engineering and Analysis* (3rd ed.). Prentice-Hall. P.28

1.2 PURPOSE

The purpose of this MBA project is to identify some of the key characteristics necessary to implement spiral development in government acquisitions, and to present lessons learned from a program office currently using a spiral development approach. This is accomplished through a case study of the Global Hawk Unmanned Aerial Vehicle (UAV) Program. This paper examines the Global Hawk's spiral development strategies, challenges, and benefits with particular attention given to successful tactics and potential pitfalls of using this acquisition approach.

1.3 RESEARCH QUESTIONS

The focus of the research for this report centers on two areas. First, it examines actual Global Hawk Systems Group issues through the first question:

> ***What are the technical, program management, financial, and logistical benefits and challenges experienced by Global Hawk as a result of implementing a spiral development approach?***

The report will also convey overarching lessons learned that can be applied broadly to most programs implementing a SD approach through the second question:

> ***What are some of the lessons learned from the Global Hawk program's spiral development approach that could be useful to other program managers directing a spiral development program?***

1.4 METHODOLOGY

The research methodology for this project consists of three major components. The first component is a literature review on spiral development, evolutionary acquisition, and agile acquisition published in scholarly journals, trade journals, and DoD doctrine. The second piece includes interviews with key IPT members from the GHSG, performing the following functions: program management, financial management, systems engineering, requirements planning, and logistics. Those interviewed will not be identified by name, but by function. The third component is an analysis of the information obtained from research and interviews to identify some of the key characteristics necessary to implement spiral development in government acquisitions.

1.5 ORGANIZATION

Chapter I is a broad overview of this report and lays out the general roadmap of the research through a purpose, research questions, organization and methodology.

Chapter II provides an overview of spiral development policy and programmatic implications through a literature review. This literature review explores recent articles from scholarly journals and trade journals and focuses on four areas impacted by spiral development: technology development and fielding, program management, financial management, and logistics.

Chapter III presents the methodology behind the interviews with GHSG team members. This is followed by an introduction to the Global Hawk and provides a short history of the weapon system, its mission and technical capabilities. Next it provides details on Global Hawk’s operational experience and typical flight operations. It concludes with a look at Global Hawk’s programmed spirals and projected strategy.

Chapter IV answers the research questions proposed in Chapter I by providing a description and analysis of the major spiral development benefits and challenges in the technology development and fielding, program management, financial management, and logistics areas within the Global Hawk program. The chapter concludes with a description of lessons learned from this trailblazing office that can be applied to future spiral development endeavors.

Chapter V summarizes the findings of the research and presents recommendations for further research and study.

1.6 BENEFITS OF STUDY

The primary benefit of this study is the identification of program management lessons learned from the Global Hawk spiral development process. This study gives future program managers insight into Global Hawk's spiral development strategy and its effects. Finally, those program managers can profit from the experiences of current program personnel and use those lessons to help enable success in fielding complex systems in today's dynamic military acquisition environment.

1.7 SUMMARY

This chapter began the research on spiral development and the key characteristics necessary to implement SD in any DoD acquisition program. It discussed the background and purpose behind the research. In addition, it introduced the research questions and methodology undertaken. Finally, it provided the framework for the report format, and listed the benefits of this study. The literature review in the next chapter dives into SD and the focus areas of this study.

II. LITERATURE REVIEW

This chapter introduces the concepts of spiral development, evolutionary acquisition, and agile acquisition. Its purpose is to explore a sample of recent literature on the subject and to dissect some of the conjecture on this relatively new approach to acquisition.

2.1 INTRODUCTION

Military acquisitions are constantly under scrutiny for cost overruns, sliding schedules, and user disillusionment at the hands of useless products. According to Johnson and Johnson, every few years "the acquisition process for defense in the United States is considered broken… [and] seems ripe for repair."[3] Holding true to recent transformation initiatives, the Assistant Secretary of the Air Force for Acquisition, Marvin Sambur, aptly named the USAF's initiative Agile Acquisition. In a recent interview, Sambur stated that the goal of agile acquisition is "building credibility within and outside the acquisition community and reducing cycle time by a ratio of 4:1."[4] Agile acquisition has only recently been used in the Air Force, and is referred to more commonly as evolutionary acquisition (EA).

To start this literature review, the reader must first have a working knowledge of the topic at issue: EA. EA is defined by Department of Defense (DoD) Instruction 5000.2 as a procurement strategy that puts new technology into the hands of the warfighter, or users, quickly. The instruction further calls for continuous requirements definition to ensure the acquisition community stays abreast of user needs.[5] The result of EA should be getting today's technology into the hands of the users as soon as possible.

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[3] Johnson, W. M., & Johnson, C. O. (2002) "The Promise and Perils of Spiral Acquisition: A Practical Approach to Evolutionary Acquisition." *Acquisition Review Quarterly*.. p. 175.

[4] "Interview with Marvin Sambur, Assistant Secretary of the Air Force (Acquisition)." *Program Manager*. July/August 2003. p. 34.

[5] US Department of Defense. (2003 May) "The Defense Acquisition System." DoD Directive 5000.1. p. 3.

Since the focus of this MBA project is on a specific Air Force program, it is necessary to examine the Air Force's preferred acquisition strategy.

The Air Force narrows the scope of EA in Air Force Instruction (AFI) 63-123, calling it a strategy to field a system quickly, with an intention to "develop and field additional capabilities [through] successive increments."[6] Farkas and Thurston synthesized the definitions as "a strategy that develops and delivers . . . an initial capability and continues the development and production of the system to provide additional capability over time."[7]

EA is a strategy. Spiral development (SD) is one approach. DoD 5000.2 defines SD as a process in which users have identified their desired capability, but do not understand exactly what the end state requirements will be.[8] In this process, the acquisition community will rapidly field a system based on current technology balanced with user requirements. The process calls for future development spirals in which feedback from the users, lessons learned from the field, and maturing technology are incorporated into the design.

The Air Force again refined the scope of SD's definition in AFI 63-123, calling it an "iterative set of sub-processes that may include: establish performance objectives; design; code, fabricate, and integrate; experiment; test; assess operational utility; make trade offs; and deliver [the system]."[9] The instruction further discusses typical characteristics of a SD process. The process normally calls for a team seeking to mitigate risk through firm development, production, test, and fielding plans. Farkas and Thurston give a practitioner's definition of SD as an "iterative process that includes collaboration with the stakeholders/users and continuous feedback . . . to provide the best possible

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[6] US Department of the Air Force. (2000) "Evolutionary Acquisition for C2 Systems." Air Force Instruction 63-123. para 3.1.

[7] Farkas K. & Thurston, P. (2003, Jul/Aug) "Evolutionary Acquisition Strategies and Spiral Development Processes: Developing Affordable, Sustainable Capability to the Warfighters." *Program Manager*. p. 11.

[8] US Department of Defense. (2003, May 12) "The Defense Acquisition System." DoD Directive 5000.1. p. 4.

[9] US Department of the Air Force. (2000) "Evolutionary Acquisition for C2 Systems." Air Force Instruction 63-123. para 4.1.

capability for a specific increment."[10] Thus, EA is the established acquisition *strategy*, and SD is the DoD's go-to *process* to rapidly field new technology.

SD differs from the traditional incremental development strategy, in which the program office plans to acquire the "entire end-state capability, as well as firm definitions of interim increments" in the first block.[11] If the user desires changes after receiving the system, traditionally, the program office plans for them through preplanned product improvements (P3I).

Spiral development became the cornerstone to the USAF acquisition community in June of 2002, when Dr. Sambur issued a new policy memorandum. In the letter, he stressed the importance of rapidly fielding systems. To do this, the Air Force's preferred method, according to Sambur, should now be SD.[12]

The policy letter sent ripples across the acquisition community. Since this new memorandum, there have been numerous articles written on programmatic successes and hazards of the SD process. This is evident in just a short list of literature: "Promise and Perils of SD"; "Conflict and Ambiguity Implementing EA"; and "Spiraling Cost."

This literature review analyzes the most recent text on EA and SD with the intention of extracting key elements crucial to successful implementation. The review looks at a collection of articles and text on the subject through the following themes: technology development and fielding; program management; financial management; and logistics.

2.1.1 TECHNOLOGY DEVELOPMENT AND FIELDING

A program's successful technology development hinges on several important factors, but begins with a sound systems engineering approach. Blanchard and Fabrycky,

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[10] Farkas K. & Thurston, P. (2003, Jul/Aug) "Evolutionary Acquisition Strategies and Spiral Development Processes: Developing Affordable, Sustainable Capability to the Warfighters." *Program Manager*. p. 13.

[11] US Department of Defense. (2004, Oct) "Defense Acquisition Guidebook, Version 1.0." para 3.1.4.

[12] Sambur, Marvin, (2002, July) *Reality-Based Acquisition System Policy for all Programs*

in *Systems Engineering and Analysis*, note that systems engineering is unlike mechanical or civil engineering. It is a well planned, highly disciplined approach, mixing the right technology and management techniques in a synergistic manner.[13] Due to the broad scope of systems engineering, it is not feasible to address every aspect crucial to SD. However, three concepts that work hand in glove with systems engineering were prevalent in recent SD literature. They are technology maturity, requirements employment strategy, and configuration management.

2.1.1.1 TECHNOLOGY MATURITY

Technology maturity at the early stages of a program is critical to fielding a system on time. Expeditious fielding is one of the main tenets of EA and SD. Compared to traditional programs, SD programs only have a fraction of the time normally dedicated to technology development. Even minor development setbacks in a SD program can have a catastrophic impact on an already compressed schedule.

A 2005 General Accountability Office (GAO) report studying technology maturity of major weapon systems stated that immature technology is the leading cause of weapon system cost overruns and late deliveries. Program offices must ensure adequate maturity prior to integration to reduce program risk. The report continued, stating: "successful programs make a science and technology organization, rather than the program or product development manager, responsible for maturing technologies."[14] With this type of third party evaluation of technology status, a program office is not susceptible to unrealistically propitious schedules and cost estimates based on overly optimistic contractors and program managers.

There are many methods of measuring technology maturity for transition readiness. Mahafza, Componation, and Tippett address several of these methods, although not specifically for a SD program. Their report details a new method of

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[13] Blanchard B. S. & Fabrycky, W. J. (1998) *Systems Engineering and Analysis* (3rd ed.). Prentice-Hall. p. 18.

[14] General Accountability Office. (2005, Mar) "Defense Acquisitions: Assessment of Selected Major Weapon Systems: GAO-05-301. p. 6.

analyzing readiness. This new methodology, the Technology Performance Risk Index (TPRI), combines two previous methods, Technical Performance Measure (TPM) and Degree of Difficulty (DD), to calculate a numerical risk value. The authors contend that using TPRI "reduces the probability associated with immature technology being transitioned to a weapon system prematurely."[15] Again, although this TPRI was not introduced solely for SD programs, it could be fruitful in using a SD approach as programs look for the right time to fold in new technologies.

2.1.1.2 REQUIREMENTS EMPLOYMENT STRATEGY

A program's requirements employment strategy ties in well with disciplined systems engineering. The employment strategy balances current technology with warfighter's needs. The program office does not necessarily field capabilities in the same order as the users originally prioritized. There may be a good reason to jockey the list to reduce cost.

Johnson and Johnson discuss the importance of the requirements employment concept, stating that users must "trust the program office to combine capabilities where efficiencies occur, sometimes taking the requirements a little out of order."[16] They continued with the example of:

> An engine upgrade (Priority 4) with an alternate fuel certification (Priority 6) in Spiral 1 and Spiral 2 containing the navigation avionics upgrades (Priority 5)…. The program office would explain that by doing both the engine and the fuel upgrade in the same spiral, the program could save resources in the wind tunnel tests.[17]

In this scenario, the savings in combined testing of the articles outweighed the benefits of fielding the navigations upgrade in the first spiral even though it had a higher

[15] Mahafza S., Componation, P, & Tippett, D. (2005, Spring) "A Performance-Based Technology Assessment Methodology to Support DoD Acquisition." *Defense Acquisition Review Journal*. p. 281.

[16] Johnson, W. M., & Johnson, C. O. (2002) "The Promise and Perils of Spiral Acquisition: A Practical Approach to Evolutionary Acquisition." *Acquisition Review Quarterly*. p. 183.

[17] Ibid. p. 183.

priority than the fuel certification. In any case, user trust (discussed in the program management section of this literature review) is critical to the employment strategy.

2.1.1.3 CONFIGURATION MANAGEMENT

A typical concern of a program's systems engineering approach is configuration management. With several spirals in a SD program, there is a good chance for multiple configurations. Johnson and Johnson address the advantages of SD over the traditional acquisition program in regards to this issue. "With . . . block approaches and P3I efforts, multiple configurations currently exist on many fielded programs . . . With a spiral approach, the program expects, plans, and condones different configurations, allowing capability to be fielded more quickly."[18]

The 2004 *Defense Acquisition Guidebook* addresses the importance of configuration management, stating EA "has increased the importance of traceability in program management . . . Due to the nature of [EA], design, development, deployment and sustainment can each be occurring simultaneously for different system increments."[19] Program offices must enforce, through constant communication and clarification, the configuration management plan. This MBA project will explore the challenging task of configuration management in a system that simultaneously has a spiral fielded, one in production, and one in development.

The three technological areas discussed above are not independent; they are synergistic. If a program office does one well, success is magnified in the other areas. The acquisitions community must strive to balance the maturity, strategy and configuration management particularly well in spiral programs.

[18] Johnson, W. M., & Johnson, C. O. (2002) "The Promise and Perils of Spiral Acquisition: A Practical Approach to Evolutionary Acquisition." *Acquisition Review Quarterly*. p. 183.

2.1.2 PROGRAM MANAGEMENT

Managing the cost, schedule and performance of a DoD weapon system is an arduous task. With fewer people, less funding, and more time constraints than ever before, a program manager (PM) faces many daunting challenges. These challenges can be exacerbated in a SD program, as the program is constantly evolving via spirals. This means *more* cost, schedule and performance changes that must be managed. PMs and their IPT members, especially the end-user (or warfighter) will benefit from an understanding of these problems and their potential resolution. The literature reviewed discussed several strategies to reduce the risk associated with program management in a dynamic SD environment. Two critical themes consistently appeared in this area: IPT communication and user trust.

2.1.2.1 IPT COMMUNICATION

Within the military, the most prevalent enabler of communication success is the IPT. An IPT normally consists of, but is not limited to the PM, government engineers, test and evaluation planners, financial managers, contracting officers, logisticians, the contractor, and a user representative. Boehm discusses the importance of including all stakeholders in a spiral development program. They warn against omitting key members of an IPT, stating "excluding [IPT members] from the development cycles can lead to win-lose situations, which generally devolve into lose-lose situations." [20] One way to combat communications decay is with regularly scheduled IPT meetings with consistent and empowered team members.

The 2004 *U.S. Air Force Transformation Flight Plan* mandates using a "collaborative requirements process [demanding] that the war fighter, acquirer, and tester work as one team… throughout the development of a weapon system."[21] The users must

[19] US Department of Defense (2004, Oct) "Defense Acquisition Guidebook, Version 1.0." para 4.1.4.

[20] Boehm, B, & Hansen, W. J. (2001, Jan) "Understanding the Spiral Model as a Tool for Evolutionary Acquisition." University of Southern California Special Report. p. 6.

[21] US Department of the Air Force. (2004) *The US Air Force Transformation Flight Plan.* p. 23.

work with the acquirer to prioritize the list of capabilities that they need fielded, while the testers must develop a realistic plan to seamlessly verify system readiness.

Rippere suggested an IPT structure consisting of the "requirers", the technologists, the testers, the acquirers, and industry. He stressed the importance of industry involvement, stating that contractors "must be included in the initial concept development, traditionally a government-only activity" for SD to work.[22] Direct industry-user communications give realistic expectations for initial and follow-on spirals.

Regardless of the motivation for involvement, it appears the more up front involvement by all stakeholders, the better. This sounds great in theory, but managing all of these players can be an onerous task. Nevertheless, the program manager should find that open, early, and consistent communication will help warfighters receive today's technology today.

2.1.2.2 USER TRUST

User trust is critical in any acquisition process. The SD process calls for a much higher degree of user trust of the acquisition community than other acquisition processes. Over the years, the old requirements generation process created an engrained negative perception among users. As a general rule, if the user did not demand every capability in the first delivery, they would never see the envisioned end item. Users were under the distinct impression that anything conceded in the first weapon system block would be considered superfluous and never delivered at a later date. Thus, the user's strategy has always been to demand a 100-percent solution from the start.

This mentality changes in SD, starting with the Initial Capabilities Document (ICD). Major General Robert A. Nadeau, Commanding General Research Development and Engineering Command, stated "despite its shortfalls [a UAV] flying new is better than nothing."[23] He went on to state that users must concede to an 80, 60, or even a 40

[22] Rippere, R. B. (2004) "Acquisition transformation: Lead into gold?" *Defense & AT-L.* p. 38.

[23] Nadeau, R. A., Maj Gen, (2005, May 17-18) 2nd Annual Acquisition Research Symposium, Monterey, CA, *Comment on Spiral Development with regard to Raven hand-launched UAV.*

percent solution, understanding that not every requirement will be met in the first spiral. The using command must have full confidence that their acquisition team will not let them down in the future.

Novak, Sthultz, Reed, and Wood agree. The first of ten recommendations for executing EA is that "the user must accept the fielding of a 60% to 80% solution".[24] However, while users may understand this concept, there is always a semblance of doubt, especially when considering the volatility of congressional military funding.

2.1.3 FINANCIAL MANAGEMENT

All programs, whether developed using SD or via incremental acquisition, are subject to strict financial regulations. The DoD's use of multiple "colors" of money for different appropriations (Research Development Test and Evaluation [RDT&E], procurement, operations and maintenance [O&M], etc.) often puts DoD financial managers into inflexible positions due to the difficulty of moving money between appropriations. In fact, if a program uses the wrong type of funds for a contract action or if a program gets into a contract without enough funding to cover the terms of the contract, that program violates federal law. Additionally, the DoD's highly complex Planning Programming Budgeting and Execution System (PPBES) does not allow for short term flexibility with funding. It forces a program to look over the horizon at future funding requirements, and where to fold them into the budget.

Certainly, both the strict financial regulations and PPBES serve important roles to eliminate illegal financial transactions and increase the chances of financial accountability. However, as they exist today, they make the financial manager's job more difficult in a spiral development environment. This section reviews literature that discussed financial management challenges and opportunities under a SD setting via two lenses: budgeting and execution.

[24] Novak R.M., Sthultz T. T., Reed T. S., and Wood C. C. (2004) "Evolutionary Acquisition: An Analysis of Defense Procurement and Recommendations for Expanded Use." *Journal of Public Procurement*. Vol. 4 (2). p. 256.

2.1.3.1 BUDGETING

The literature reviewed highlighted three prominent budgeting challenges as a result of taking a SD approach: unstable future funding; mismatching with the Program Objective Memorandum (POM) cycle; and Life Cycle Cost (LCC) challenges.

First, due to the iterative nature of SD and its required flexibility to move requirements in and out of spirals, out-year funding becomes unstable. This, of course, is at odds with the current financial construct, which requires stability. Novak, et al. agree, "funding and requirements stability are critical to the effective execution of EA as they are in any acquisition."[25] This is not an easy task. The following pieces of literature provide a few recommendations for this issue.

Johnson and Johnson state, "the financial community and leadership must accept that content in later spirals is subject to change based on technology and user needs. They must accept placeholders in some cases and budget for that."[26] This is a fundamental shift in the way budgeting is done. It could potentially require policy change and certainly a cultural change within the DoD. On that point, Hansen, Foreman, Albert, Axelband, Brownsword, and Forrester agree, "the Office of the Secretary of Defense (OSD) and the services should promote an understanding of the unique funding needs of the EA/SD programs by the financial management community (to avoid cuts of funds essential to the implementation of flexible requirements and milestones)."[27] These suggestions illustrate the importance of open communications between all stakeholders in a new DoD landscape driven by SD's nuances.

Partially as a result of unstable requirements and funding, the mismatch between spiral development and the POM cycle is a challenge. Slate stressed, "The biggest

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[25] Novak R.M., Sthultz T. T., Reed T. S., and Wood C. C. (2004) "Evolutionary Acquisition: An Analysis of Defense Procurement and Recommendations for Expanded Use." *Journal of Public Procurement*. Vol. 4 (2). p. 261.

[26] Johnson, W. M., & Johnson, C. O. (2002, Summer) "The Promise and Perils of Spiral Acquisition: A Practical Approach to Evolutionary Acquisition." *Acquisition Review Quarterly*. p. 186.

[27] Hansen, W.J., Foreman, J.T., Albert, C.C., Axelband, E., Brownsword, L.L. & Forrester, E.C. (2001, Aug) "Spiral Development and Evolutionary Acquisition: The SEI-CSE Workshop, September 2000." *Special Report CMU/SEI-2001-SR-005*. p. 40.

problem is the time necessary to get the money for these programs into the POM cycle."[28] He opines that because of this challenge, financial mangers must be given the liberty to change the funding amounts down the road without penalty. Hansen, et al. share the concern that "EA/SD are not synchronized with the budget process . . . [and] current contractual procedures are not sufficiently flexible."[29] To help alleviate this concern, they propose three measures: 1) Congress should improve the current funding model for all DoD projects; 2) OSD should create measures to synchronize funding with program milestones; and 3) Services should budget for certain areas such as Command and Control in the aggregate versus individually.[30] These measures would be nothing short of a dramatic paradigm shift in the DoD financial arena, and probably would not happen unless the entire DoD embraced this movement in resounding force.

Finally, performing LCC analyses is more difficult with SD. Since each spiral contains a different baseline configuration, it is easy to focus on the current baseline being developed instead of the aggregate program costs or total ownership cost (TOC) of the system. Indeed, Novak et al. state, "EA essentially requires a more complex life cycle cost analysis since the number of variables increases with unstable and dynamic requirements."[31] In studying TOC reduction, Boudreau and Naegle discuss many ways to reduce TOC such as using tools like tradeoff analysis, reliability-centered maintenance, performance-based logistics and activity-based costing.[32] Clearly, financial managers in spiral development programs need to remain focused on TOC reduction and LCC management to prevent cost overruns and keep their programs

[28] Slate, A.R. (2002, May/Jun) "Evolutionary Acquisition: Breaking the Mold—New Possibilities from a Changed Perspective." *Program Manager.* p. 15.

[29] Hansen, W.J., Foreman, J.T., Albert, C.C., Axelband, E., Brownsword, L.L. & Forrester, E.C. (2001, Aug) "Spiral Development and Evolutionary Acquisition: The SEI-CSE Workshop, September 2000." *Special Report CMU/SEI-2001-SR-005.* p. 39.

[30] Ibid. p. 52.

[31] Novak R.M., Sthultz T. T., Reed T. S., and Wood C. C. (2004) "Evolutionary Acquisition: An Analysis of Defense Procurement and Recommendations for Expanded Use." *Journal of Public Procurement*. Vol. 4 (2). 2004. p. 257.

[32] Boudreau, M. W., Naegle, B. R., (2003) "Reduction of total ownership cost." NPS-AM-03-004.

executable. After all, cost overruns were a chief complaint of the traditional acquisition system, and a main reason for the DoD's shift towards acquisition reform, which led to EA and SD.

2.1.3.2 EXECUTION

In addition to the budgeting challenges arising from SD, funding execution is also challenging under the SD paradigm. Current SD literature consistently showed two challenging SD execution areas in particular: susceptibility to funding cuts and management difficulties with increased simultaneous use of multiple colors of money.

First, a program using SD is perhaps more susceptible to funding cuts than a traditional program. In one article regarding the challenges of SD, the authors point out, "Spiral acquisition is inherently flexible and could lead to budget cutbacks in difficult times because the program can weather the impacts without catastrophic failure . . . [they are] viewed as a "cash cow" for less flexible acquisitions."[33] In other words, it can be difficult to execute funds if DoD leadership assumes a SD program can "take a hit" this year since they can adjust their schedule to fold in capabilities in a future spiral. This is akin to robbing Peter (an SD program) to pay Paul (a non-SD program) without any future payback.

Next, financial management may become more difficult due to the increase in concurrent use of funding appropriations. One working group at Carnegie Mellon University's Software Engineering Institute anticipates, "In the year 2010, evolutionary acquisition enhanced by spiral development will have a greater degree of concurrent research and development, production, and operation for a given program than occurs today."[34] This makes sense given that at any point in a program's lifetime, Spiral 1 could be operating in the field (spending *O&M* funding), with Spiral 2 undergoing final

[33] Johnson, W. M., & Johnson, C. O. (2002, Summer) "The Promise and Perils of Spiral Acquisition: A Practical Approach to Evolutionary Acquisition." *Acquisition Review Quarterly*. p. 186.

[34] Hansen, W.J., Foreman, J.T., Albert, C.C., Axelband, E., Brownsword, L.L. & Forrester, E.C. (2001, Aug) "Spiral Development and Evolutionary Acquisition: The SEI-CSE Workshop, September 2000." *Special Report CMU/SEI-2001-SR-005*. p. 36.

operational testing (spending *procurement* funding) while Spiral 3 technologies are under development (spending *RDT&E* funding). This concurrency in spending occurs with traditional acquisition during upgrades, for example. But, it would seem that SD would increase the instances of concurrency. Because of this, Novak et al. recommend new training and flexibility for financial managers in an EA setting.[35]

From both a budgeting and execution perspective, the literature reviewed pointed out several important considerations when using a SD approach. Whether dealing with an unstable funding problem within a budgeting framework or trying to manage multiple colors of money at once, a financial manager must be aware of SD's budgetary and execution pitfalls and have proper training to handle this new era of agile acquisition.

2.1.4 LOGISTICS

DoD logistics personnel could become more non-supportive of spiral development than any other member of a program's IPT. Many logistical jobs such as parts management are made more complex due to spiral development. The literature reviewed discussed some of the biggest logistical challenges and opportunities with SD in the area of integrated logistics support (ILS).

2.1.4.1 INTEGRATED LOGISTICS SUPPORT (ILS)

There are ten elements within the DoD's ILS framework. They are maintenance planning; supply support; design interface; packaging, handling, storage and transportation; manpower and personnel; training and training support; technical data; facilities; support equipment; and computer resources support. Although all of these elements are affected by using SD or EA, this review focuses on maintenance planning, design interface and support equipment.

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[35] Novak R.M., Sthultz T. T., Reed T. S., and Wood C. C. (2004) "Evolutionary Acquisition: An Analysis of Defense Procurement and Recommendations for Expanded Use." *Journal of Public Procurement*. Vol 4 (2). p. 257.

Lack of maintenance planning is a common theme across the literature reviewed. Novak et al. state, "while the core advantage of EA is the faster fielding of technology, this may result in less planning for long-term supportability and maintainability of the asset."[36] In one of the few articles written on logistics and spiral development, Farmer, Fritchman, and Farkas agree, "planning can be more complex when attempting to support multiple increments, rather than one final delivery."[37] They go on to discuss how all of the planning documents and decisions take on additional complexities under SD/EA.[38]

Next, while design interface seems more complex with SD, it may be more apt to succeed in a spiral development environment. The design interface element essentially tries to capture long-term supportability issues within the up-front system design. Choosing components with higher reliabilities can help, as well as using a modular design for easier integration of future component improvements. According to some, design interface is "far and away the most powerful [ILS element]."[39] In a traditional acquisition program, this element must be demanded up front, before a design gets locked in. Many times this does not happen. In SD, however, each new spiral provides another opportunity to influence the design to enhance long-term supportability. Farmer et al. state: "Under an EA strategy, the opportunity to improve reliability on a fielded system happens much sooner and more often in a program as design changes with each increment could lower TOC, as well as improve operational performance."[40] For design interface to have an impact, the IPT must involve logistics personnel early and continuously as spirals develop.

The third ILS element prominent in the literature reviewed is support equipment. Support equipment is "all the equipment required to support the operation and

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36 Novak R.M., Sthultz T. T., Reed T. S., and Wood C. C. (2004) "Evolutionary Acquisition: An Analysis of Defense Procurement and Recommendations for Expanded Use." *Journal of Public Procurement*. Vol. 4 (2). p. 243.

37 Farmer, M. E., Fritchen, G. J., & Farkas, K. J. "Supporting the Fleet in the 21st Century: Evolutionary Acquisition and Logistics." *Air Force Journal of Logistics,* 2003. Vol. 27 (Iss. 1). p. 28.

38 Ibid. p. 29.

39 Farmer, M. E., Fritchen, G. J., & Farkas, K. J. "Supporting the Fleet in the 21st Century: Evolutionary Acquisition and Logistics." *Air Force Journal of Logistics,* 2003. Vol. 27 (Iss. 1). p. 29.

40 Ibid. p. 29.

maintenance of weapon systems."[41] This element is vital to the supportability of the system in the field. Farmer et al. are poignant when they state, "a weapon system delivered to the field without support capability is little more than a static display."[42] Due to SD's iterative character, support equipment is needed as each spiral is delivered. Using existing support equipment is normally the most cost effective solution. If each spiral requires different support equipment, the problems with configuration control and configuration management will be exacerbated. Thus, the use of modularity and scalable capacity are vital for future spirals.[43]

In discussing the elements of ILS, the literature reviewed contained both challenges and opportunities for logistics in the SD/EA environment. Conventional wisdom with DoD acquisitions tells us that roughly 60 to 70 percent of a system's total cost occurs during system sustainment. Since the logistics piece is the core of sustainment, the stakes are high indeed.

2.2 SUMMARY

The technology development and fielding, program management, financial management and logistics areas are well-established pieces of DoD's acquisition puzzle. However, under SD, new opportunities and challenges arise in each of these areas. The literature reviewed highlighted several areas of concern and room for potential growth. In addition, some of the literature highlighted varying methods to overcome challenges and heighten success, and emphasized areas where future investigation is needed. It is with this foundation that our case study of one program embracing SD, the Air Force's Global Hawk UAV, begins.

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[41] Ibid. p. 30.

[42] Farmer, M. E., Fritchen, G. J., & Farkas, K. J. "Supporting the Fleet in the 21st Century: Evolutionary Acquisition and Logistics." *Air Force Journal of Logistics,* 2003. Vol. 27 (Iss. 1). p. 28.

[43] Ibid. p. 30.

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III. GLOBAL HAWK PROGRAM

This chapter provides a brief description of the interview and information gathering methodology. This is followed by a short history of the Global Hawk, its mission and technical capabilities. It further provides details on some of the operational experiences and typical flight operations. The chapter concludes with a look at Global Hawk's programmed spirals and projected strategy.

3.1 INTERVIEW QUESTION BACKGROUND

As discussed in the methodology section of Chapter I, the most crucial information in this report was obtained through interviews with key Global Hawk Systems Group (GHSG) personnel. In structuring the interview questions, we wanted to obtain the most comprehensive and influential lessons learned from the interviewees. To accomplish this, the interview questions were kept broad so the interviewee could address their foremost opinions on managing a spiral development program.

The interviews were performed in an informal, threaded discussion of program operations guided toward the two research questions. Interviews would normally start with basic information on the subject's role in the GHSG, followed by generic research questions. These questions would be tailored to the person's subject matter. For example, the logistics managers at the program office were able to give detailed information on current and past logistical issues in the GHSG. They further voiced some of the spiral development benefits and challenges, and with some conjecture, analyzed how spiral development has either exacerbated problems or created opportunities that would not have existed otherwise.

This threaded discussion approach allowed us to obtain the "bold faced" problems confronting program managers in the GHSG. Chapter II covered documented problems with spiral development to date. There were issues that we expected to hear, and did hear from the interviewees. There were some surprises that had not been expressed in any literature. Had it not been for the open, threaded discussions, these items might not have been brought up. We have tried to publish lessons learned from the interviews to which future program managers leading a spiral development effort should pay particular attention.

Some of the basic information in this chapter was obtained through these discussions, as well as recent program office briefings and published documents. To start, a brief history of the program is necessary to fully appreciate some of the problems faced by its managers.

3.2 HISTORY

Pilots in the United States Air Force undergo years of training before ever flying a combat mission. The price of this training, coupled with the growing casualty aversion of Americans, makes the price of losing a pilot all the more detrimental. With advancement in technology, there are certain missions that can be performed without putting a life in harm's way. Besides preventing loss of human life, Unmanned Aerial Vehicles (UAVs) have more design trade space available since they need no human centered systems on board such as life support systems, on-board displays, ejection seats, etc. They can also be designed to go beyond the limits a human can endure such as G-force limitations for extreme maneuvers.

In the 1990s, the Air Force contracted out a series of purpose-built unmanned reconnaissance aircraft systems including the RQ-1 Predator, RQ-2 Pioneer, RQ-3 Dark Star, RQ-4 Global Hawk, RQ-5 Hunter, RQ-6 Outrider, and RQ-7 Shadow. Although several of these programs have since been cancelled, two are at the forefront of military news: the Predator and the Global Hawk. This MBA project focuses on the Global Hawk.

Figure 1: RQ-4A Global Hawk

The RQ-4A Global Hawk began in 1995 as an Advanced Concept Technology Demonstration (ACTD) built by Ryan Aerospace (who was later purchased by Northrop Grumman). The ACTD was aimed at giving the warfighter a rapidly developing prototype intended for reconnaissance activities. After a series of successful performances in joint USAF/Royal Australian Air Force (RAAF) military exercises, the USAF decided to purchase the UAV, entering the Engineering and Manufacturing Development phase in March of 2001.

Soon after September 11, 2001, the Global Hawk was put into action, using the ACTD platforms to fly real-world missions supporting Operation Enduring Freedom (OEF). Since the aircraft was not fully operational, their end-user, Air Combat Command (ACC) pilots, had not been fully trained to fly the small fleet of RQ-4A aircraft. Thus, Air Force Materiel Command (AFMC) test pilots commanded the aircraft in theater during the transitional stage. These pilots flew over 1,000 hours in the first year of operations, accumulating over 15,000 images in the first year alone.

3.3 MISSION

The Global Hawk helps provide battlefield commanders with a complete battlespace picture by performing virtually the same roll and mission as the aged USAF U-2 manned aircraft with some technology improvements. Specifically, it provides "high altitude, deep look, long endurance intelligence, surveillance, and reconnaissance (ISR) capability that complements space and other airborne collectors during peacetime, crisis, and war-fighting scenarios."[44]

3.4 CAPABILITIES

The Global Hawk system is comprised of an aircraft, a ground segment, and a support segment. The aircraft has a high resolution Synthetic Aperture Radar (SAR) capable of penetrating cloud cover. Further, it has Electro-Optical/Infrared (EO/IR) imagery capability. Its High Altitude Long Endurance (HALE) capability means the RQ-4A models can loiter at 65,000 feet and travel over 12,000 nautical miles. It can take detailed images of an area approximately the size of Illinois in a 24-hour period. As a cog in the system-of-systems, the RQ-4A can relay information almost instantaneously to troop commanders at the field level via satellite. Table 1 summarizes some of the RQ-4A's key characteristics and performance metrics.

Characteristics			**Performance**	
Weights			Altitude	65,000 ft
	Empty	9,200 lbs	Endurance	35 hrs
	Payload	2,000 lbs	Loiter Velocity	342 ktas
	Takeoff Gross	26,500 lbs	Range	12,500 nm
Length		44 ft		
Wingspan		116 ft		
Height		15 ft	*Source: GHSG*	

Table 1: Key Characteristics of the RQ-4A Global Hawk

The ground segment includes the Mission Control Element (MCE) located at Beale Air Force Base, CA, and the Launch and Recovery Element (LRE), which is forward deployed with the aircraft.

The support segment includes elements such as aerospace ground equipment, tech orders, spares, support equipment and training.[45] As with most systems, the support segment is vital to keep the overall system mission capable.

[44] US Department of the Air Force (2005, Feb). *Exhibit R-2, RDT&E Budget Item Justification-PE0305220F Global Hawk Development/Fielding.* p. 202-2.

3.5 KEY PERFORMANCE PARAMETERS

ACC has identified the following four Key Performance Parameters as outlined in Table 2 below. Like any program, if any of these KPP's is not met, the program is in danger of cancellation.

KPP - Endurance—28 Hours - Airspace Coordination—Worldwide employment - Ground Station—Operators perform NRT mission control, monitoring and updates/modifications - Satisfy 100% of critical top-level IERs *Source: GHSG*

Table 2: Global Hawk ORD KPPs

3.6 OPERATIONAL EXPERIENCE

From an operational perspective, in addition to OEF, the prototypes have continued operations during Operation Iraqi Freedom (OIF), and its combat successes are impressive. Table 3 provides a few examples of Global Hawk's operational experiences in both OEF and OIF. Unfortunately, in OIF, the Air Force has experienced a high failure rate, crashing two in-theater assets. This is a relatively high percentage of losses, but it is a prototype aircraft. Obviously, the risk of accidental loss of human life is considerably less than the risk associated with a manned aircraft. The GHSG was able to take that risk into consideration when deciding to field the unproven vehicle.

Operation Enduring Freedom • GH in theater 11 Nov 01 - 28 Sep 02 • 63 combat missions • 1,237 combat flight hours • 17,338 images collected • 20+ program office and 30+ contractor personnel deployed *Source: GHSG*	**Operation Iraqi Freedom** • GH in theater 8 March - 2 May 03 • 16 combat missions - 357.2 combat flight hrs • Flew only 3% of air breathing Image Intel missions & 5% of hi-altitude recon sorties yet accounted for 55% of the Time Sensitive Targets (TSTs) generated to kill air defense equipment. • Over 4800 Images including: 13 Full SAM Batteries--50 SAM Launchers--300 SAM Canisters 70 SAM Missile Transporters--300 tanks (38% of Iraq's Known Armor) *Source: GHSG*

Table 3: Global Hawk's Operational Experience

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[45] US Department of the Air Force (2005, Feb). *Exhibit R-2, RDT&E Budget Item Justification-PE0305220F Global Hawk Development/Fielding*. p. 202-2.

3.7 TYPICAL GLOBAL HAWK OPERATIONS

In a typical operation, operators at a forward operating location initiate a Global Hawk flight using the LRE. Once airborne, the aircraft is handed over to the MCE located at Beale AFB, CA where trained ACC pilots remotely fly the UAV for the entire operational mission. For landing, control of the aircraft is transferred back to the LRE operators at the forward operating location who launch and recover the aircraft.

3.8 THE RQ-4B AND RESULTANT PROGRAM RESTRUCTURING

Because of the RQ-4A's rousing successes, the Air Force decided to build a brand new, larger version of the Global Hawk: the RQ-4B. The RQ-4B is a much larger, more capable version of the existing A-model necessary to carry better sensor payloads and to gain multi-intelligence capabilities on a single aircraft.[46] Table 4 shows a comparison of some of the key characteristics of the RQ-4A and the RQ-4B.

Characteristic	RQ-4A	RQ-4B
- Payload capacity	2,000 lbs.	3,000 lbs
- Takeoff weight	26,750 lbs.	32,250 lbs.
- Wingspan	116.2 ft.	130.9 ft.
- Fuselage length	44.4 ft.	47.6 ft.
- Endurance	31 hrs.	33 hrs.
- Loiter at 60,000 ft.	14 hrs.	4 hrs.
- Ave speed @ 60,000 ft.	340 knots	310 knots
- Approximate range	10,000 n. miles	10,000 n. miles
	Source:	*GAO-05-6 Report*

Table 4: RQ-4A versus RQ-4B

This B-model incorporates advanced technologies in several areas and requires both new processes and tooling for manufacturing. To accommodate these changes, the Air Force has restructured the program twice since 2001. This restructuring extends the development period from 7 yrs to 12 yrs and shrinks the procurement period from 20 yrs to 11 yrs. This of course, translates into dramatic funding restructuring.

46 US General Accountability Office (2004 Nov) Unmanned Aerial Vehicles: Changes in Global Hawk's Acquisition Strategy are Needed to Reduce Program Risks: GAO-05-6. p. 6.

The RDT&E funding requirements increased in total and are spread over a longer development timeline (12 yrs). The procurement funding requirements were compressed dramatically to show huge increases in the near term to accommodate a shorter procurement period (11 yrs). Figure 2 shows these differences in funding requirements before and after the restructuring.

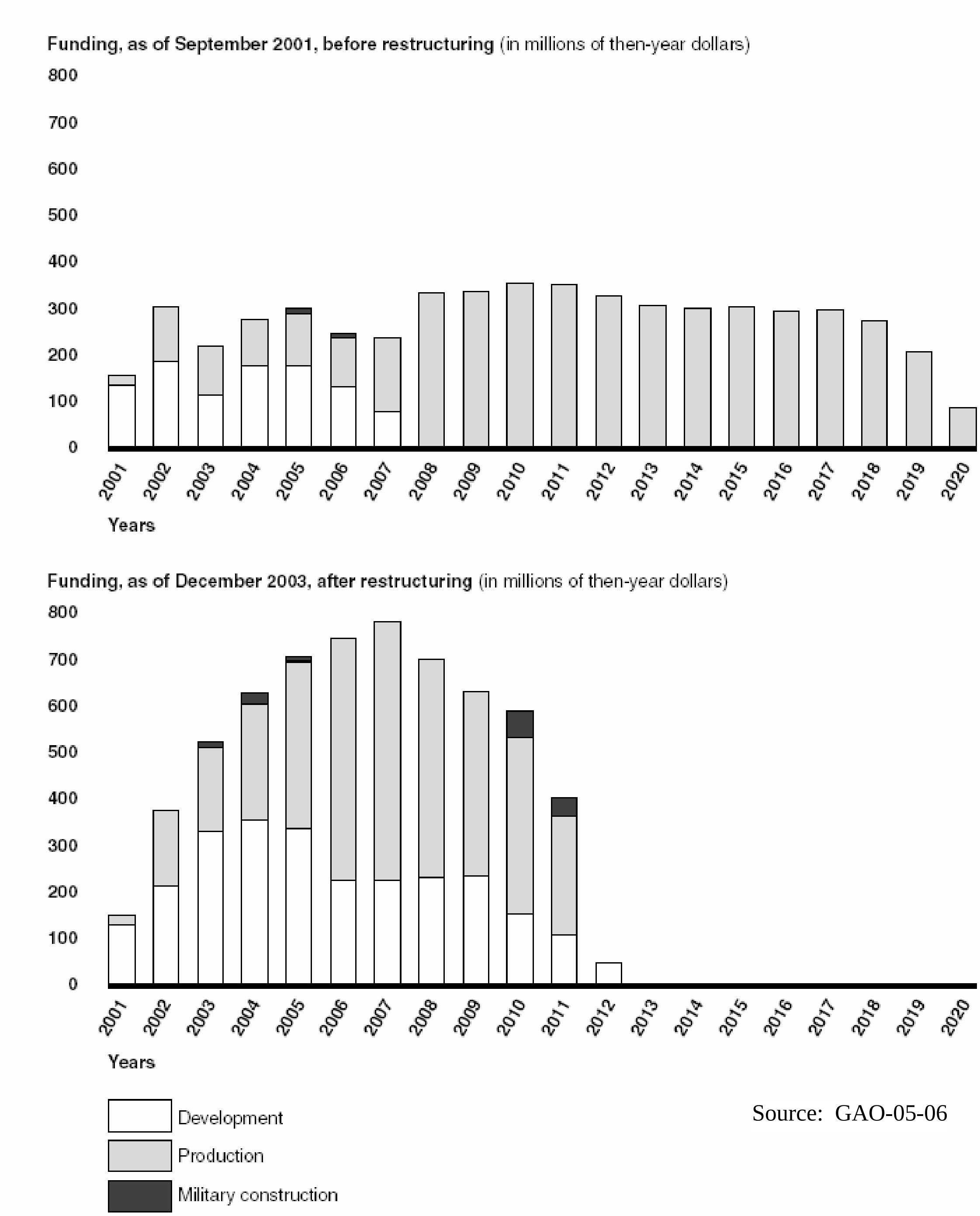

Figure 2: Funding Requirements Change due to Global Hawk Restructuring

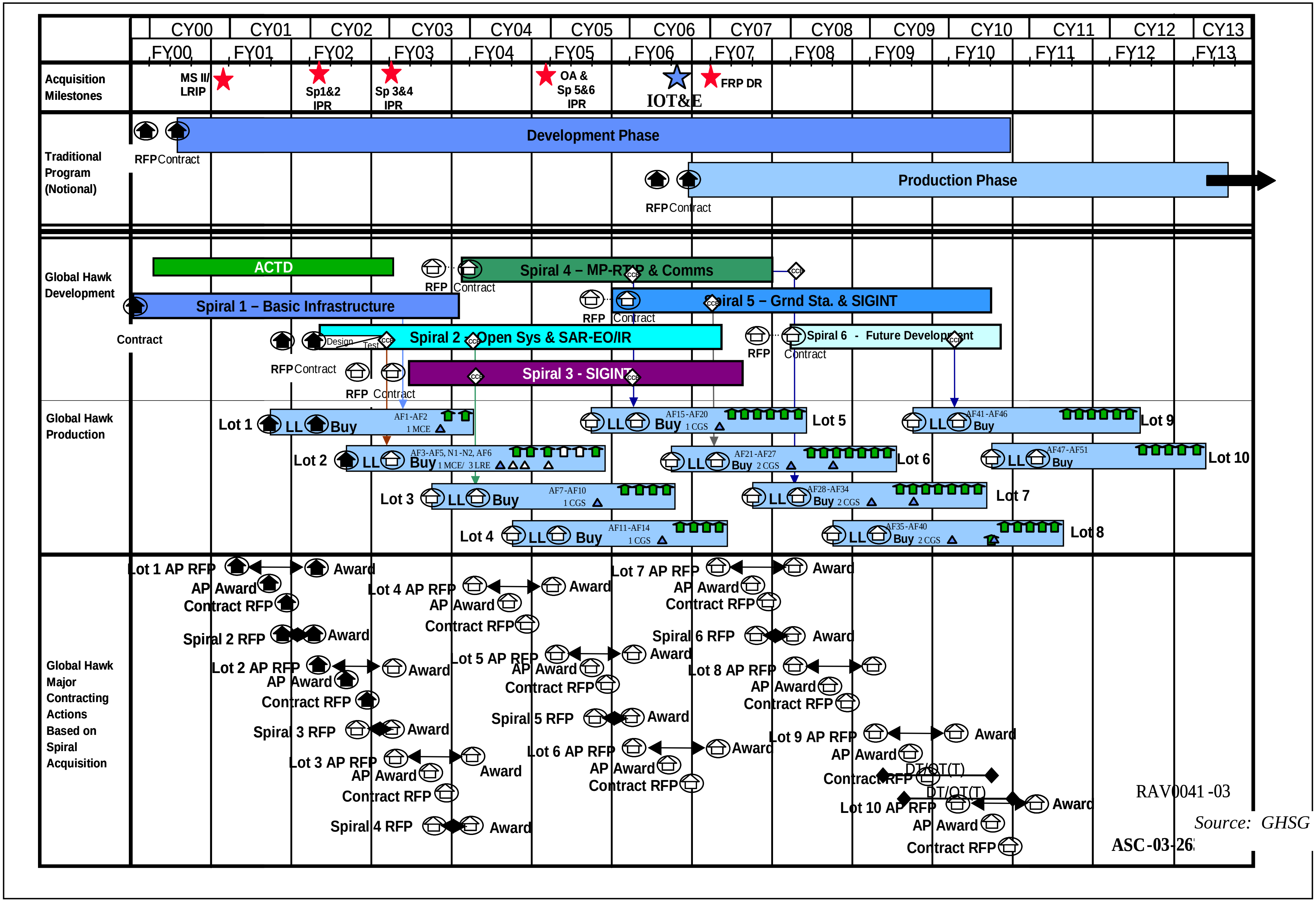

Figure 3: Global Hawk Schedule

The restructured program calls for a reduction in total aircraft procured from 63 to 51. Of the 51 aircraft being procured, 7 are RQ-4A's and 44 will be RQ-4B's. In addition, the GHSG will produce 10 ground stations instead of the 14 originally planned. Figure 3 above shows the current program schedule, juxtaposing Global Hawk's spiral development approach and its multiple spirals and aircraft builds against a traditional approach. This shows that by the time a traditional acquisition approach would be in the midst of awarding a contract for production, the GHSG will have already built 15-16 Global Hawks.

Each spiral contains different desired capabilities. The Global Hawk program is starting each new spiral on a yearly basis. Figure 4 shows the complement of those capabilities by spiral.

Spiral 1:
Operationalize Existing System- Worldwide operating capability
- Sustainable support system

Spiral 2:
Expanded Imagery Intelligence (IMINT), initial Signal Intelligence (SIGINT)- Near horizon standoff EO/IR/SAR
- Limited SIGINT augments IMINT mission

Spiral 3:
Full-spectrum SIGINT- Signals Intelligence to support mid-scale engagements
- Machine level horizontal integration capable
- Defensive threat awareness

Spiral 4:
Improved Radar- Track quality ground moving target identification
- Airborne surveillance
- Enhanced airspace operations and survivability

Spiral 5-6:
Full-spectrum operations- Full horizontal integration
- Expanded communications
- Extreme environment / Nuclear, Biological, and Chemical (NBC) ops

Source: GHSG

Figure 4: Global Hawk Spiral Composition

In addition to the Air Force procurement strategies, The US Navy is slated to receive two RQ-4A aircraft. Likewise, several U.S. allies including Britain and Germany have expressed interest in the Global Hawk although no funding has been committed yet.

3.9 SUMMARY

This chapter covered Global Hawk's history, mission, some operational experiences, and program strategy. This information, along with the spiral development background from Chapter II, provided crucial information necessary for a discussion of GHSG's spiral development benefits and challenges.

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IV. ANALYSIS AND LESSONS LEARNED

This chapter analyzes the benefits and challenges of using a SD approach from the Global Hawk program's perspective. Based on several interviews with GHSG personnel, numerous themes re-emerged when discussing the benefits and challenges of GHSG's use of SD. This report looks at those themes grouped by our four key areas of study: Technology Development and Fielding, Program Management, Financial Management and Logistics. Finally, this chapter concludes with a description of overarching lessons learned to benefit any program manager of a spiral development program.

4.1 TECHNOLOGY DEVELOPMENT AND FIELDING

4.1.1 CHALLENGE: CONFIGURATION MANAGEMENT

Configuration management is extremely challenging for the Global Hawk program. One Global Hawk manager characterized the problem as follows: "Configuration management problems are monstrous for us. The answer that Global Hawk has chosen is to do configuration management the hard way, plane by plane, and ground station by ground station."[47] Currently, there are eight aircraft fielded with eight "vastly different configurations."[48] Good configuration management is difficult to do with Global Hawk's compressed schedule and heavy personnel workload.

As discussed in Chapter II of this report, with several spirals in a SD program, there is a good chance for multiple configurations. Thus, configuration management is a large challenge in a program like Global Hawk, which has aircraft in development, production and deployment simultaneously.

GHSG's solution of doing configuration management "the hard way" is at odds with such a compressed schedule and minimal manning. They currently have personnel

[47] Subject A. Telephone Interview. GHSG program management. Aug 2005.

[48] Subject F. Telephone Interview. GHSG logistics. Aug 2005.

dedicating time to building a baseline matrix tracking each aircraft's configuration.[49] They track both the software and hardware configuration by aircraft and ground station. This is manageable now, with only a small number of aircraft.

However, as the number of fielded aircraft increase rapidly over the next several years, this plane-by-plane management will be increasingly burdensome. As squadrons of Global Hawks are put into operation, the variations of components will drive higher levels of spares and headaches for maintainers.

Although there is no easy solution for this problem, program managers need to expect it and concentrate configuration management efforts from the start. This could mean an increase in configuration management staffing and oversight, the introduction of automated configuration management tools, and keeping strict adherence to Configuration Control Board (CCB) rules.

4.1.2 CHALLENGE: SOFTWARE DEVELOPMENT

Multiple software development problems, inherent to any DoD acquisition, were exacerbated with Global Hawk's SD approach. Specifically, the ground station mission planning software had several developmental problems that were made worse by both the SD approach and the concurrency that occurred between development and production. The program experienced large cost and schedule slips because of this issue. [50]

The DoD recognizes the difficulties inherent with acquiring software. The Air Force's *Guidelines for Successful Acquisition and Management of Software Intensive Systems* states, "DoD has had a distressing history of procuring elaborate, high-tech, software intensive systems that do not work, cannot be relied upon, maintained, or modified."[51] This inherent complexity is made worse in an environment where the main thrust behind the program is to field capabilities quicker. In addition, most software

[49] Subject G. Telephone Interview. GHSG engineering. Aug 2005.

[50] Subject A. Telephone Interview. GHSG program management. Aug 2005.

[51] Air Force Software Technology Support Center, (2000) *Guidelines for Successful Acquisition and Management of Software Intensive Systems* Version 3.0. p 31.

development efforts are under-estimated in terms of schedule and cost. Further, once a software development effort is behind schedule, adding more software programmers actually slows the process even further due to training the new programmers on what's been done. Thus, the Global Hawk's problem with the ground station mission planning software is not rare. But it is still a problem.

To help remedy this situation, the GH program can pursue a number of actions, such as: control the requirements creep to reduce the impact on software modifications; use Computer Aided Software Engineering (CASE) tools to help with planning and estimation of resources; and rigorously monitor appropriate metrics such as "function points" and other "effort metrics" to measure progress accurately.

4.1.3 CHALLENGE: SYSTEMS ENGINEERING AND REQUIREMENTS CONTROL

The systems engineering Vee model, shown below, is one way to depict how to properly consider all requirements within a program. Moving down the left-hand side, requirements are decomposed and defined from the system level down to the component level. Going back up the right-hand side, requirements are integrated and verified through testing. All along the way, different design reviews are used as "gates" to ensure all system requirements are completely addressed.

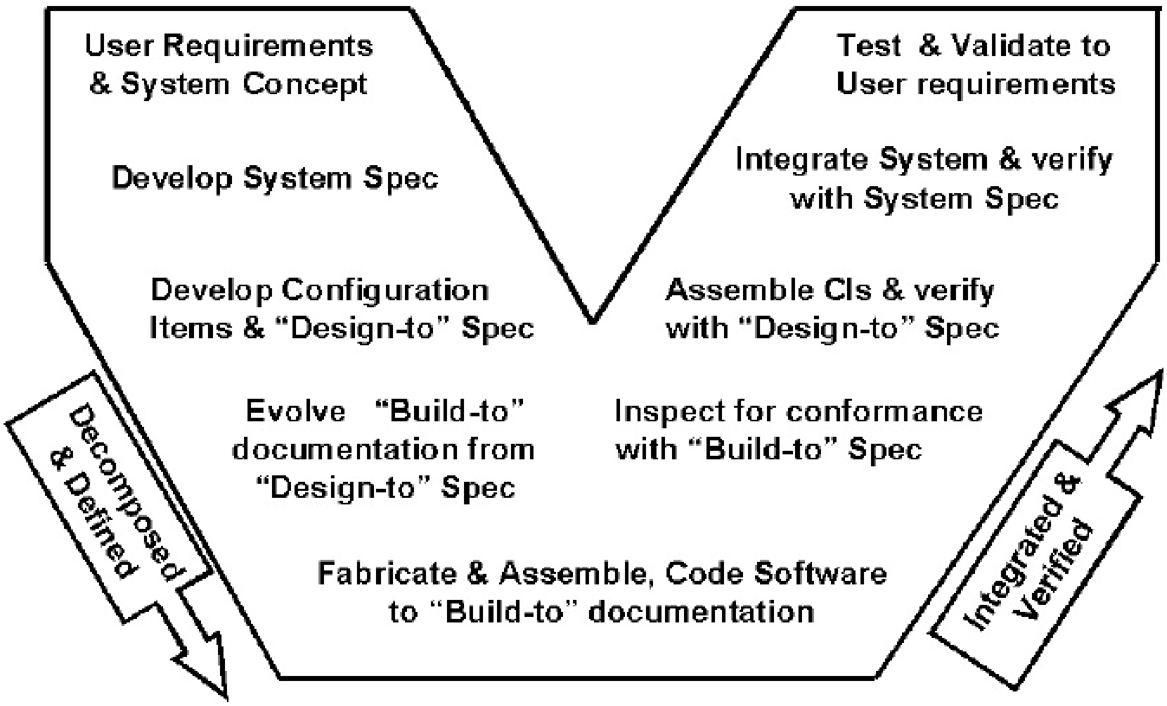

Figure 5: Systems Engineering Vee Model[52]

Because GH is using a SD approach, time is very critical, perhaps even more so than in a traditional acquisition program. As a result, the GHSG had originally chosen to save time by cutting down on the SE process. According to one GHSG manager, to save schedule they did not fully utilize the SE process and did not fully decompose any new requirements.[53]

Saving schedule is always on the radar of DoD program managers. However, skipping steps in the SE process is not the answer. Although it may save some time initially, it will have a huge impact on the program in the long run. As seen in the SE

[52] Dillard, John T. (2003, Sept) "Centralized Control of Defense Acquisition Programs: A Comparative Review of the Framework from 1987-2003", Acquisition Research Sponsored Report, Naval Postgraduate School, Monterey, CA

[53] Subject A. Telephone Interview. GHSG program management. Aug 2005.

Vee model, only after a complete decomposition can requirements be fully fleshed out and brought back together into subsystems for testing and ultimately synthesized as a completed system.

One change the Global Hawk program recently made to combat this problem is adding rigorous requirements control for all new requirements. They have established a bi-annual requirements working group (RWG) that marries up the user (ACC/DRH) with GHSG team members to discuss system requirements and their proper placement within any given spiral. The collaborative approach ensures IPT commitment to the requirements employment strategy discussed in the literature review of this report.

After recognizing the need to have a disciplined SE approach with regards to requirements, the GHSG injected more detail to the requirements process. One manager at the GHSG detailed this new approach, saying, "For any new requirement that goes before the RWG, we require complete requirements traceability from top to bottom, full SE decomposition, and cost estimates."[54] This approach steers both users and planners away from a requirements free-for-all. Instead, it appropriately forces everyone to recognize the far-reaching impacts of adding requirements, and to do a complete analysis *before* the RWG even meets.

4.1.4 BENEFIT: CAPABILITY "FOLD-IN"

The Global Hawk ACTD aircraft, currently on their third deployment for the Global War on Terrorism (GWOT), learned about critical upgrades on the first and second deployments. Because of their SD approach, they have been able to insert lessons learned from this operational experience into the rest of the fleet. Because the end-state is not locked in with a spiral development approach, they have the flexibility to do this. Two specific examples are the integration of the Air Defense Situation Integrator (ADSI) and the Secure Instant Messaging System (SIMS).

[54] Subject A. Telephone Interview. GHSG program management. Aug 2005.

The Global Hawk initially used preplanned routes to avoid interference with the U-2. This was an undesirable fact of life since they were not able to make significant route deviations once airborne. But after adding ADSI to the remaining deployed Global Hawk, "we have a tremendous increase in our situational awareness and we can do things on the fly."[55]

The second capability added, SIMS, "allows the operator, Combined Air Operations Center, and exploiters to do real time changes to the mission to increase effectiveness tremendously."[56] This capability is essentially a SIPRNET-like connection that provides a secure, real-time chat capability between all pertinent parties to take advantage of narrow windows of opportunities that come about during any given mission.

In this instance, using a spiral development approach paid dividends to the program office. This is an area where spiral development can positively affect warfighters. Since development (and funding) continues with every spiral, the lessons learned with each deployment experience can be folded in to future spirals as appropriate. One challenge with this capabilities fold-in is jumping the financial hurdles of last minute changes. This challenge is discussed in the Financial Management section later in this chapter.

Another challenge with folding in spirals is verification (testing) in a compressed schedule. To reduce testing time, the program can agree to an integrated testing plan or a combined operational test. An integrated test helps reduce the amount of resources required for testing and details areas to combine testing efforts. Combined developmental and operational testing is defined as "a single, combined test program that produces credible qualitative and quantitative information that can be used to address developmental and operational issues."[57] Barnette agrees, stating "combined DT&E and OT&E…will assist in obtaining the goal of seamless verification by helping to eliminate duplicate test requirements, correcting scheduling inefficiencies, [and] identifying

[55] Subject A. Telephone Interview. GHSG program management. Aug 2005.

[56] Ibid

[57] US Department of Defense (2004, Oct). *Defense Acquisition Guidebook*, Version 1.0. Washington, DC: Author. p. 9.3.3.

performance concerns early."[58] Additionally, early operational assessments can reduce the amount of overall testing needed and limit the number of surprises in major tests.

4.2 PROGRAM MANAGEMENT

4.2.1 CHALLENGE: CONCURRENCY

There are several interpretations of what concurrency means in a DoD acquisition environment. For this report, we define concurrency as simultaneous development and production. According to several members of the GHSG, concurrency is a major management challenge to the program. The government is agreeing to by a product while it is still in development. It puts lots of risk on the government that may lead to severe consequences in a number of areas.

In a traditional acquisition program, concurrency would be less prevalent, since events are usually performed in sequence, not in parallel. A certain amount of concurrency in a program can aid in fielding a system faster. However, too much concurrency can put a significant amount of risk on the program. The GAO tells us, "Historically, programs with high degrees of concurrency are at greater risk of cost, schedule, and performance problems than programs with less overlap of development and production."[59] However, the SD approach encourages working in parallel. This gives the opportunity for situations where the government tries to save schedule by performing tasks in parallel that probably should be performed in sequence.

The November 2004 GAO report on Global Hawk's restructuring highlighted Global Hawk's use of concurrency as an extremely risky move. The report reads, "Global Hawk's highly concurrent development and production strategy is risky and runs counter in important ways to a knowledge-based approach and to DoD's acquisition

[58] Barnette, G. L. (2005). Test and Evaluation in a Dynamic Acquisition Environment. *Defense Acquisition Review Journal*, p. 340

[59] General Accountability Office (2004, Nov). Changes in Global Hawk's Acquisition Strategy are needed to Reduce Program Risk: 05-6. Washington, DC: Author. p. 10

guidance."[60] The restructured program and resultant compressed schedule are challenging at best, perilous at worst. This concurrency approach calls for the Air Force to invest in 20 of the 44 RQ-4B's before a production representative RQ-4B is fully flight-tested.[61] In its first of three recommendations, the GAO called for the Air Force to re-visit its extensive use of concurrency, due to the high risk.[62]

GHSG personnel readily acknowledge the existence of the concurrency risk. One manager stated, "We are signing up to buy things at the same time we are developing them, which is inherently very risky. We know that concurrency hazards contributed to the RQ-4B overruns."[63] But, the Air Force non-concurred to the GAO recommendation calling for more sequential development and production, stating the Global Hawk's "evolutionary acquisition strategy balances acquisition risk with military need."[64] The Air Force maintained that the GAO's sequential approach would delay the program by "several years", and due to the resultant production break, would impose a cost impact of $400M. [65]

One initial way the GHSG is trying to combat concurrency problems is by performing more pre-spiral studies to ensure that all capabilities slated for a specific spiral are truly ready for incorporation.[66] This certainly does not solve the problem, but it is a good way to gain confidence in the technology levels destined for a production run in the near future.

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[60] General Accountability Office (2004, Nov). Changes in Global Hawk's Acquisition Strategy are needed to Reduce Program Risk: 05-6. Washington, DC: Author. p. 1

[61] Ibid, p. 3

[62] Ibid, p 18

[63] Subject A. Telephone Interview. GHSG program management. Aug 2005.

[64] General Accountability Office (2004, Nov). Changes in Global Hawk's Acquisition Strategy are needed to Reduce Program Risk: 05-6. Washington, DC: Author., p. 31

[65] Ibid, p. 31-33

[66] Subject A. Telephone Interview. GHSG program management. Aug 2005.

In total, the concurrency risk continues to loom large over the Global Hawk program, and will continue for the foreseeable future. One GHSG manager called “being very wary of using concurrency” as one of his top two lessons learned for future spiral programs.[67]

4.2.2 CHALLENGE: WORKLOAD

The Global Hawk program is in development, production, testing and deployment all at the same time. This means much more work in shorter periods of time versus a traditional program. However, the program does not have a resultant plus up in personnel. In fact, they must do more with less people. This means managing daily work priorities that are very challenging and certainly dynamic.[68]

This problem is probably fairly common across any SD program. In addition to Global Hawk’s SD approach, their high level of concurrency contributes to this challenge. Further, the streamlining of the DoD’s workforce exacerbates this problem since there is nothing suggesting an increase in acquisition personnel in the future. This requires a higher caliber workforce.

One way to combat this challenge is to have a robust training program in place for all personnel. The GHSG must establish and continually improve upon a rigorous training regiment for everyone, with an emphasis on cross training between functional areas. For example, all GHSG financial managers should understand the requirements process, and the importance of configuration control. Likewise, all engineers should understand the key DoD financial management tenets and constraints.

Another must-have is a heavy reliance on IPTs with both experience and authority.[69] If the IPT does not have both of these attributes, they will be powerless. The

[67] Subject A. Telephone Interview. GHSG program management. Aug 2005.

[68] Ibid

[69] General Accountability Office (2001, Apr). DOD Teaming Practices not Achieving Potential Results: 01-510. Washington, DC: Author. P. 3.

GHSG should empower IPTs to make key decisions in their respective arenas with the full responsibility that goes with that distinction.

4.2.3 BENEFIT: FLEXIBILITY

One of GHSG's biggest benefits from using spiral development is flexibility in planning. They are able to shuffle around requirements within and between spirals based on changing user need and management direction.[70]

Flexibility certainly comes inherently with spiral development. But, this flexibility is predicated on excellent communication. The user, contractor, and entire government acquisition team must be constantly aware of each other's needs and actions. This can be challenging from a resource perspective, especially with a challenging schedule and limited resources.

The GHSG has taken advantage of spiral development's inherent flexibility to try to give the user as much capability as possible in a short timeframe. They understand the importance of meeting user needs as they arise, especially with the lessons coming out of OEF and OIF. This approach is good for the user, but can be tough to sustain the pace of change if all desired changes are left unchecked. But, if the GHSG can keep a strong balance between this flexibility and solid requirements control through their RWG, they can sustain long-term successes for both GHSG managers and end-users.

4.3 FINANCIAL MANAGEMENT

4.3.1 CHALLENGE: PPBE SYSTEM SHORTFALLS

The dynamic technical composition of each spiral presents a financial management challenge. A Global Hawk financial manager described the planning uncertainty this problem gives as his biggest financial challenge. He said, "because we don't know exactly what's going in to each spiral--and if we do, it still may change--we

[70] Subject B. Telephone Interview. GHSG financial management. Aug 2005.

have to look much closer at what type of funding we need and when. In addition, the DoD's PPBE system hamstrings us."[71] A second GHSG manager described the PPBE challenges as follows, "the PPBE system doesn't fit into our scheme since it drives us to set dates and funding amounts, but it goes against the tenets of SD, where you don't really know dates."[72]

The DoD's PPBE system is extremely complex, with its multiple types of funding and each type's unique usage requirements. A DoD financial manager must be able to plan for, and request the proper type of funding several years in advance to effectively budget for and execute a program. In this case, a spiral's uncertainty, which is a plus for adding requirements in a flexible manner, is a negative for the financial manager to ensure the correct type of funding is in place for each spiral. In addition, the low fidelity in the required out year budgetary submissions (where one can make the most difference in a program's budget), is often coupled with an underestimate of the amount of funding needed because technology is assumed to "be there" by then.

In characterizing this problem, an Air Force O-5 Program Element Monitor for several Air Force space programs at the Pentagon, gave a good "bottom-line" example with real fiscal years attached to it. In reference to the intersection of PPBES and the realities of managing a program, he stated, "So…if you think you need lots of additional funds for your program, you should estimate your requirements by Dec 05 for the funds you'd like to have in FY12/FY13. The challenge, of course is that the fidelity of your estimates 3-9 years out isn't that great."[73] This is a turbulent cycle from which it is hard to break out.

For the Global Hawk program, this challenge could get easier as the program's new emphasis on pre-spiral studies and RWG rigorous requirements control really takes

[71] Subject B. Telephone Interview. GHSG financial management. Aug 2005.

[72] Subject H. Telephone Interview. GHSG program management. Aug 2005.

[73] Subject I. E-mail interview. Air Force PEM. Feb 2005.

hold. Granted, the PPBE system still requires out-year planning for new capabilities, and the pre-spiral studies may not come soon enough. But, they can still be beneficial in this financial management area.

As a hypothetical example, say the RDT&E budget for spiral X (2 years out) is at $20M, and a pre-spiral study shows that a new user requirement, not originally included in spiral X, but Y, will cost an additional $5M. If the user really wants that requirement to be included in spiral X, the program will not be able to get an extra $5M within 2 years from the PPBE system due to its long cycle time. But, the program will be armed with the knowledge from the pre-spiral study that this new requirement will cost $5M, and not some overly optimistic number pulled out of thin air. They can then decide to cut out $5M elsewhere within spiral X to incorporate this new requirement. If these measures pan out, financial managers working on Global Hawk should be able to make more knowledgeable decisions on the type of funding and its proper timing for future spirals.

In addition, with time, a change in the DoD financial culture and policy might help remedy this problem, as more programs embrace spiral development. As discussed in the literature review, Johnson and Johnson state, "the financial community and leadership must accept that content in later spirals is subject to change based on technology and user needs. They must accept placeholders in some cases and budget for that."[74] This may be a long way off, but this core issue still needs to be addressed.

4.3.2 BENEFIT: NONE GIVEN

It is important to note that in all of our interviews with GHSG personnel, none gave a single financial management benefit to using SD.

4.4 LOGISTICS

4.4.1 CHALLENGE: SPARING ACTD ASSETS

[74] Johnson, W. M., & Johnson, C. O. "The Promise and Perils of Spiral Acquisition: A Practical Approach to Evolutionary Acquisition." *Acquisition Review Quarterly*. Summer 2002. p. 186.

The sole remaining deployed Global Hawk aircraft is an ACTD aircraft, as were the other deployed assets. Since they were ACTD assets, they were not spared anywhere near to the level necessary for a normal production aircraft. In fact, according to one GHSG logistics manager, the first lot of aircraft was purchased without spares, making immediate operations impossible. Even today, the level of spares is not adequate. "Thus, we are eating up our spares."[75]

ACTDs are "designed to respond quickly to an urgent joint or Service military need . . . and to place a limited but demonstrated capability into the hands of the warfighter."[76] Since ACTDs are excellent candidates to evolve into spirally developed systems, this sparing problem will likely continue to occur across the DoD. ACTD assets are meant to be "hobby shop-like", with many never going beyond a demonstration capability. Obviously, these assets are not spared properly for extended deployments like production assets are.

Therefore, there are again two requirements at odds. The military needs quick turnaround in developing ACTDs. However, if the ACTD is fielded, the users need more spares. This requires more logistics planning and funding up front, which will likely not be present in an ACTD budget.

This type of problem may never have a good solution. But, to help alleviate some pain, once an ACTD program is established as a spiral development production program candidate, a thorough logistics supportability analysis (LSA) must be accomplished quickly to address spares requirements. In Global Hawk's case, they will likely continue to do ad-hoc sparing for the ACTD assets. They are addressing the proper sparing levels for the production aircraft, as is discussed in the next section.

[75] Subject F. Telephone Interview. GHSG logistics. Aug 2005.

[76] Headquarters, United States Air Force, Future Concepts and Transformation Division (Nov 2003) *Air Force Transformational Flight Plan*, p. 23

4.4.2 CHALLENGE: SPARES REQUIREMENTS

One GHSG manager stated, “keeping track of spares requirements with multiple configurations is very challenging as each spiral is very different.”[77] This adversely affects LCC since a larger logistical footprint increases O&M funding dramatically.

As with any spirally developed program, the Global Hawk program plans to add several different capabilities in each spiral. One result of this is differing sparing requirements between spirals. Each spiral could have vastly different components, thus multiple types of spare parts for those different components. This could become a nightmare for a parts manager. In a recent study of the US Navy’s Phalanx weapon system, Apte found a similar problem, noting, “The [Phalanx’s different baselines . . . necessitate increased logistical complexity to provide necessary spares; this complexity likewise causes increased lack of availability of the maintenance expertise . . . and places a heavy burden on inventory managers to carry the required spare parts.”[78]

Since spares are so critical for operational effectiveness, logisticians must study spares tradeoffs and encourage parts commonality between spirals. This is a challenge for the Global Hawk program as it has roughly only 10 percent parts commonality between the A model and B model.[79]

A potential solution to the spares requirements for different spirals is to utilize a modular systems approach. If future components “plug and play” with the current system architecture, the version of the component used for repair purposes would not have as great an impact. For example, if the Global Hawk was truly modular, the maintainer could take either sensor version 1.0 or sensor 2.0 and install in the aircraft. Both, theoretically, should operate as they were designed. Obviously, there would be some

[77] Subject A. Telephone Interview. GHSG program management. Aug 2005.

[78] Apte, A. (2004 Oct) “Optimizing Phalanx Weapon System Life-Cycle Support.” NPS-LM-04-014. Acquisition Research Sponsored Report, Naval Postgraduate School, Monterey, CA. p. 5.

[79] Subject C. Telephone Interview. GHSG engineering. Aug 2005.

operational capability that 1.0 is not capable of performing. However, this could float the program until contractors are able to produce an adequate level of spares for the new sensor version

The second and potentially more adverse effect is an increase in LCC. Since roughly 60 to 70 percent of a program's total funding is spent on operations and maintenance, having a bigger logistical footprint due to more spares requirements hurts a program financially. Financial managers must proactively discuss the long term funding impacts of changes between spirals to give IPT members a clear picture of the total funding impact. Certainly, the best way to lower LCC is to make decisions up front, before the system is locked in. Figure 6 depicts this scenario.

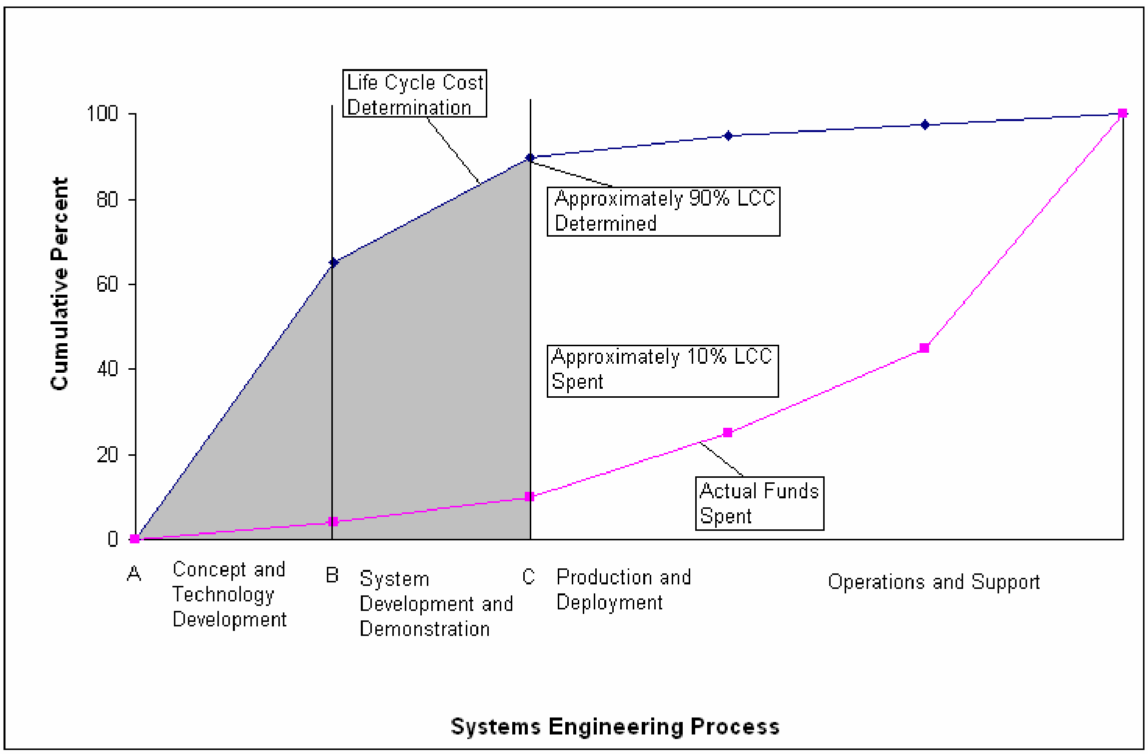

Figure 6: Impact of Decision Timing on LCC

It is always a good reminder to understand the full price tag of a proposed change up front, from a total resources perspective, and not be blinded by the technical capability increase alone. Global Hawk is taking a great step in that direction by requiring full funding impacts of new requirements in their bi-annual RWG.

4.4.3 CHALLENGE: TECHNICAL ORDERS AND TRAINING

Another logistics challenge discussed by Global Hawk personnel is the impact of multiple technical orders and training on the user. One Global Hawk manager stated, “for each spiral we need to spiral in both tech orders and training. It’s hard for our users to keep up with the amount of changes between spirals coming at them at this pace. We are using electronic tech orders, which makes things somewhat better, but it’s still a huge challenge for us.”[80]

This challenge would seem likely in any spirally developed program. In addition to having user involvement for the duration of the program, one way to dampen this challenge’s impact is to have dedicated training personnel assigned to the program. The Global Hawk program has a dedicated training person in the GHSG and another dedicated training person at the user command (ACC/DRH) to ensure training is not forgotten. They are also employing a “train the trainer” approach. In addition to having dedicated training personnel on the program, the Global Hawk program should continually streamline and automate the training process so that training events could be more easily worked into users’ schedules. Certainly, electronic tech orders are a wonderful start.

This issue may call for a complete overhaul of the way training is accomplished, but it will be worth it to reduce the burden on the user in DoD’s current high operations tempo climate.

[80] Subject A. Telephone Interview. GHSG program management. Aug 2005.

4.4.4 CHALLENGE: INITIAL RELIABILITY/MAINTAINABILITY NEGLECT

According to a GHSG logistics manager, Global Hawk did not have Reliability Centered Maintenance (RCM) or associated Condition Based Maintenance (CBM) initiatives at the beginning of the program. As a result, many of the Built-In Tests (BIT), which would ease the maintenance burden, have not yet been put in place. The GHSG is currently trying to insert these elements into spiral five. This initiative is good, but is not projected for insertion until after most of the planes have been built, creating a large retrofit requirement.[81]

In the logistics community, there are several initiatives in place to try and reduce the logistics portion of a system's LCC. Some of these are RCM and CBM. RCM "focuses on optimizing readiness, availability, and sustainment through effective and economical maintenance."[82] CBM, a subset of RCM, utilizes the latest in technology to monitor key operating aspects of a component. The sensors may monitor vibration, temperature, or other aspects to determine if the component must be inspected or replaced. CBM helps avoid much of the scheduled maintenance downtime, as the health of the components is being monitored continually.

One would not expect a "hobby shop" concept technology to have a heavy emphasis on reliability or maintainability. The *performance* of the ACTD was the primary selling point in the weapon system selection. Ryan Aerospace wanted to ensure that their aircraft out-performed the other aircraft at the fly-off. Therefore, they focused their efforts on its performance.

The Air Force could have done several things differently to alleviate this problem. They could have made the maintainability and reliability a higher-level concern in ACTDs. This is not highly recommended, as it will stifle the creativity driven ACTD efforts. Farmer et al. state: "Under an EA strategy, the opportunity to improve reliability on a fielded system happens much sooner and more often in a program as design changes

[81] Subject F. Telephone Interview. GHSG logistics. Aug 2005.

[82] Criscimagna, N. (2002, 3Q) Reliability-Centered Maintenance (RCM) *The Journal of the Reliability Analysis Center* p. 5.

with each increment could lower TOC, as well as improve operational performance."[83] However, the longer a program waits to make a change, the larger the retrofit problem.

As an example, the GHSG could have made a more concerted effort to capitalize on this opportunity, and insert the BITs in an early spiral. This is important, as BITs are found in many components of the system. Because of this broad coverage, the impact of BIT on a retrofit effort is more egregious.

To illustrate this point, if the program office decides to concentrate on the BIT for 12 different components in spiral two, they still have to modify spiral one aircraft. For GHSG, this would be approximately four aircraft to modify, or 48 BIT modifications. If they wait until Spiral five, they will have approximately 20 aircraft to modify, or 240 modifications. Compare this to a single technology insertion, where the modification to aircraft ratio is one to one, and the retrofit cost is likely lower.

4.4.5 CHALLENGE: RETROFIT EXPENSE

According to a logistics manager at the GHSG, the program office is currently working to fund approximately $600 million in retrofit bills.[84] This bill is approximate as of September 2005, and is expected to grow. The program office did not plan for these costs up front, as the original intent of the program was not to retrofit follow on spirals to a new baseline.[85]

This heavy retrofit bill will likely drive the Air Force to cut out or delay some requirements for later spirals. As requirements are delayed, this will increase the inventory of fielded aircraft that will require the retrofit, further increasing the retrofit bill.

As each aircraft comes off the production line with more capability, the existing aircraft need to be either upgraded or spared accordingly. In the GHSG, the original

[83] Farmer, M. E., Fritchen, G. J., & Farkas, K. J. "Supporting the Fleet in the 21st Century: Evolutionary Acquisition and Logistics." *Air Force Journal of Logistics,* 2003. Vol. 27 (Iss. 1). p. 29.

[84] Subject D. Telephone Interview. GHSG requirements planning. Aug 2005.

[85] Subject E. Telephone Interview. GHSG logistics. Aug 2005.

intent was to continue to provide spares for the multiple configurations. Both ACC and GHSG agreed, after not too long, that retrofitting would lead to a lower life cycle cost for the Global Hawk.

Several reasons played into this. First, a program with multiple configurations is extremely hard to manage. Second, the number of spares required is much higher than a system with a single configuration, driving up the cost. Finally, as new spirals emerge meeting new mission critical requirements, users should not be forced to operate under degraded conditions with earlier spiral models.

Hindsight being 20/20, the GHSG could have erred on the side of caution and expected the retrofit requirement. Retrofit cost must be expected and planned for in any spiral development acquisition strategy. Insisting on modularity of design up front could also help dampen the retrofit burden on a SD program.

4.4.6 BENEFIT: NONE GIVEN

Like the financial management section, out of every interview with GHSG personnel, none gave a single logistics benefit to using SD.

4.5 LESSONS LEARNED

Having analyzed several key challenges and benefits specific to the Global Hawk program's SD approach, we derived several lessons learned that are applicable to any SD program. The following section discusses each of these lessons learned, in no particular order.

4.5.1 BEWARE OF HEAVY CONCURRENCY

Global Hawk's heavy concurrency problems were the underpinnings of the first of three GAO recommendations in its report *GAO-05-06*. The program's personnel readily acknowledge this risk, yet accept it as a fact of life.

All program managers of spiral development programs should be wary of a schedule calling for significant concurrency. As stated earlier, GAO warns: "Historically, programs with high degrees of concurrency are at greater risk of cost, schedule, and performance problems than programs with less overlap of development and production."[86]

Although a compressed schedule as a result of concurrency is very attractive and seemingly doable on paper, it brings with it several risks that ultimately may doom the entire program. All program managers thinking of embracing a concurrency-laden approach should have a thorough risk management plan that specifically details measures taken to minimize these risks.

4.5.2 STAFF AND CROSS TRAIN

All DoD organizations deal with manpower shortages at some point. If a program is embracing a spiral development approach, managers should try to request the additional billets needed to meet the increased workload. In addition, they should attempt to incentivize cross training within the organization's functional areas to better equip the program's staff to deal with problems from any functional area.

4.5.3 ENSURE COMPLETE SYSTEMS ENGINEERING

For a systems engineering approach to be effective, it must be allowed to fully run its course. Taking shortcuts will negatively impact the program. As Global Hawk finally did with their RWG, one way to help prevent shortcuts is to require all new requirements to be fully decomposed to show all resultant derived requirements along with the total costs of their implementation.

[86] General Accountability Office (2004, Nov). Changes in Global Hawk's Acquisition Strategy are needed to Reduce Program Risk: 05-6. Washington, DC: Author. p. 10.

4.5.4 FOCUS ON SOFTWARE DEVELOPMENT

According to the *Guidance for the Successful Acquisition and Management of Software Intensive Systems*, "[DoD Acquisition] Programs developing large amounts of software ran 20 months behind schedule – three times longer than non-software intensive systems."[87] Because of this bleak reality, a program manager of a software intensive SD program should dedicate plenty of resources to software development management. At a minimum, a program manager should establish a separate software IPT, monitor appropriate metrics, and periodically perform no-notice progress checks to include checking the contractor's software documentation. Considering DoD's horrible software development track record, there seems to be little downside to heavy management oversight on software development.

4.5.5 CONSIDER PRE-SPIRAL STUDIES

With spiral development, a program continually looks to drop new capabilities into future spirals. Many times, the technology readiness level (TRL) of a desired new capability will not be ready for inclusion in the intended spiral. Therefore, it is critical to understand true TRLs and costs of new requirements in advance. In a spiral development with lots of concurrency, this becomes even more important. One way to help prevent premature technology transfer is to do pre-spiral studies as Global Hawk is now doing.

Another way to ensure technology is transferred at the appropriate time is to utilize a tool such as the Technology Performance Risk Index (TPRI), as discussed in Chapter II. The TPRI quantifies a new technology over time by integrating the degree of difficulty with unmet requirements, and reduces the chance of premature technology transfer.[88] It is an excellent way to track the technical progress of key new technologies.

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[87] Air Force Software Technology Support Center (2000), *Guidelines for Successful Acquisition and Management of Software Intensive Systems* Version 3.0. p 2.4.

[88] Mahafza S., Componation, P, & Tippett, D. "A Performance-Based Technology Assessment Methodology to Support DoD Acquisition." *Defense Acquisition Review Journal*. Spring 2005. p. 281.

4.5.6 MAINTAIN TECH ORDERS AND TRAINING

With a heightened operations tempo in the entire DoD, warfighters are inundated with tasks more than ever. Getting updated on tech orders and new training are critical to successful engagements using DoD weapon systems. However, with spiral development, the quicker timing of recursive spirals means updates to tech orders and training come more often. This can take a major toll on users. Just when a user feels comfortable with the system, something changes that requires new procedures and training.

Thus, spiral development program managers must be aware of this problem and plan their spirals accordingly. As Global Hawk did, using electronic tech orders and having dedicated training personnel on the IPTs are two ways to help soften the impact on users. In addition, managers should look to incorporate as much of the changes between spirals so that they are transparent to the user. This would allow the user to reap the benefits of an increase in capability, yet not have to change any tactics/procedures in the process.

4.5.7 UNDERSTAND ACTDS VS PRODUCTION PLATFORMS

This may not apply to all spiral development programs, but for those that started as ACTD programs, understanding the differences between concept demonstrations and production platforms is crucial for program managers to keep at the forefront when making decisions. To obtain the best war fighting capability, it is important to foster an environment where technological creativity is rewarded. Once authorities make the decision to transition the ACTD to a full program, acquisition managers have a duty to analyze the current design and supportability, and make changes to ensure a reliable product is fielded.

Taking an ACTD from award to fielding in minimal time comes with a price. Managers should make every effort to obtain realistic reliability, maintainability, and availability information on the system and its components. Sparing levels must be high enough to support a given operational availability, or the asset is useless in time of war.

4.5.8 CONTROL REQUIREMENTS CREEP

SD is designed to handle newly generated requirements from the users based on current operations. Folding in essential requirements in future spirals is more easily accomplished than in a traditional acquisition. However, this benefit must be kept in check to ensure there is not a requirements potluck.

As any DoD manager can attest, requirements creep is a costly problem. One GAO report discussed the impact of a requirements change early on in the Global Hawk's development, stating:

> These requirements changes increased development and procurement costs significantly. For example . . . When the Air Force's Global Hawk reconnaissance UAV was started in 1994, it was expected to have an average unit flyaway price of $10 million. Changes in the aircraft's range and endurance objectives required the contractor to modify the wings and other structural parts, and by 1999 its cost had increased by almost 50 percent.[89]

A RAND study echoed this same concern, "[Requirements creep] occurs to a greater extent in UAV programs because their mission area is usually not predetermined and because they do not usually replace an existing system. As a result, potential system requirements are not constrained, which practically guarantees additions to those requirements laid out at the program's inception"[90]

Program managers need to work hand-in-hand with the user to flesh out requirements in a collaborative and methodical manner. All parties must understand the impact of new requirements on the cost, schedule, and performance of the overall system. Pre-spiral studies and full requirements decomposition through the systems engineering process should help managers understand the realistic costs associated with satisfying each requirement.

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[89] General Accountability Office (2004, Mar). Major Management Issues Facing DOD's Development and Fielding Efforts: 04-530T. Washington, DC: Author. p.13-14.

[90] Drezner, J. A. & Leonard R. S. *Innovative Development: Global Hawk and Dark Star—Their Advanced Technology Demonstration Program Experience*. RAND Corporation, 2002, p. 33

4.5.9 CONSIDER COMPONENT RELIABILITY EARLY

Although easier said than done, this is an important aspect of fielding a reliable system. Operations and sustainment of a program make up nearly 60 to 70 percent of the life cycle cost for most acquisitions. Early logistics decisions in a spirally developed procurement will likely have a more profound impact on life cycle costs than a program developed using an incremental approach. In other words, a program which ignores reliability concerns in the short term with a plan for improving in follow on spirals is set up for failure. Programs must concentrate on improving immature system level reliability from the start.

This can be accomplished through predictive estimates of component reliability, laboratory tests, actual demands during testing, and early feedback from initial users. As true reliability will only be understood over great lengths of time, it is additionally important to try and maintain a high level of parts commonality from spiral to spiral.

4.5.10 CONFIGURATION MANAGEMENT CHALLENGE

Configuration management will be more intensive in a SD program. There are multiple versions to manage due to several spirals, models, retrofits, and limited upgrade parts availability. Adding concurrency to this SD program puts even more stress on the configuration management team. This becomes exponentially more difficult to manage as more weapon systems are fielded. Logisticians and operators need to be kept abreast of weapon system configurations as they plan for spare and support equipment requirements as well as day-to-day missions. Automated configuration management tools and increased staffing could help in configuration management.

4.6 SUMMARY

This chapter analyzed some of the benefits and challenges of using a SD approach from the Global Hawk program’s perspective. It looked at these challenges and benefits in four key areas: Technology Development and Fielding, Program Management, Financial Management and Logistics. We then analyzed the overarching lessons learned to benefit any program manager of a spiral development program. The final chapter of this report summarizes these findings and makes recommendations for further study.

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V. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

This section summarizes the research on the use of SD in the GHSG and resultant recommendations and lessons learned for future SD program managers. Although SD is a program management challenge, the main advantage is fielding an emerging capability quickly. One GHSG manager emphasized this point by saying:

> SD gets you a large percentage of your end-state quickly. But it doesn't get you all of it. As people start to get close to what they're looking for, they get unsatisfied because they want the end-state fast. But the approach isn't to solve every problem before production. It's to get a useful capability fast, then upgrade over time. There is a "Time Value of Capability" that must be reiterated to everyone.[91]

In today's challenging DoD environment, program managers must perform a challenging juggling act of alphabet soup to keep major acquisition programs under control: ensure high TRLs, accurately track LCC, enforce the KPPs, utilize RCM, reduce TOC, and the list goes on. While all these items may be more arduous in a SD program due to the compressed schedule and propensity for increased concurrency, they are all very useful. However, the thrust of this report was not intended to create another time-consuming management task. It is a report *from* practitioners *to* practitioners on potential pitfalls and benefits in managing a SD program.

5.1 CONCLUSIONS

All of the research questions are answered in depth in Chapter IV of this report. The answers are summarized below.

Research Question 1: What are the technology development and fielding, program management, financial, and logistical benefits and challenges experienced by Global Hawk as a result of implementing a spiral development approach?

[91] Subject A. Telephone Interview. GHSG program management. Aug 2005.

Technology Development and Fielding:

Challenge: Configuration Management – Configuration management is hard to do in a compressed schedule and under a heavy workload, as seen in Global Hawk. Multiple spirals will drive multiple fielded versions. SD will also create versions in virtually every stage of the acquisition cycle, from concept to sustainment. Currently, Global Hawk is managing configuration the hard way, plane-by-plane, ground station by ground station. Configuration management will become exponentially more difficult as additional weapon systems are fielded. Program managers can increase configuration management staffing and oversight, utilize automated configuration management tools, and ensure strict adherence to Configuration Control Board (CCB) rules to combat some of these problems.

Challenge: Software Development – The ground station mission planning software for the Global Hawk had several developmental problems that were worsened by the SD approach. This is not an uncommon problem, and program managers can combat the challenge by controlling requirements creep, using CASE tools to estimate resources, and track appropriate software development metrics.

Challenge: Systems Engineering and Requirements Control – GHSG had initially reduced the amount of decomposition for new requirements to save on time. This reduced the fidelity of understanding cost and schedule impacts when planning future spirals. They have since required full "requirements traceability from top to bottom, full SE decomposition, and cost estimates" for all requirements that are presented to the RWG.[92] This technique avoids an impulsive requirements free-for-all that may occur with a SD program.

Benefit: Capability "Fold-In" – The GHSG has been able to fold in capabilities in later spirals that were not envisioned from the start, but were recognized upon fielding the weapon system. These capabilities were needed based on OEF and OIF combat, and were folded in very quickly. Two examples of successful "fold-in" are the ADSI and

[92] Subject A. Telephone Interview. GHSG program management. Aug 2005.

SIMS requirements. Because of this flexibility, ACC is able to maximize the overall real-time capability utilization of the Global Hawk.

Program Management:

Challenge: Concurrency – High levels of concurrency put tremendous risk on the government, especially when the developing technology has a low technology readiness level (TRL). In Global Hawk's case, the Air Force will have purchased 20 of the 44 RQ-4Bs before the aircraft is fully flight-tested, a move that is "highly risky" according to the GAO. Managers at the GHSG now rely on pre-spiral studies to assess the technology maturity prior to transfer. Although these studies are useful, there is still significant concurrency risk in the Global Hawk program.

Challenge: Workload – SD brings with it a heavier manpower workload and thus changing daily job priorities within the GHSG. Global Hawk personnel need to manage requirements in multiple spirals in a tightly compressed schedule. To combat this, the GHSG must establish and improve upon its training program. Additionally, it must ensure the IPTs have the right caliber of expertise and authority to effectively make decisions.

Benefit: Flexibility – GHSG is able to shuffle around requirements within and between spirals based on changing user need and management direction. The GHSG has taken advantage of spiral development's inherent flexibility to try to give the user as much capability as possible in a short timeframe. But, they demand extensive information on all new requirements going before their RWG, to include requirements traceability and cost estimation to help retain requirements control.

Financial Management:

Challenge: PPBES Shortfalls – GHSG is programmed in a multi-year PPBES cycle, managed by three-year military personnel, funded in one-year appropriations. These rigid timelines and rules are at odds with SD's goal of flexibility, and unknown future requirements. This drives program managers to try and estimate costs three to nine years out for future spirals. This is very difficult considering the dynamic composition of each spiral, and the low fidelity of out year estimates. It is hard to meet the PPBES cycle timelines and still retain the flexibility necessary to inject new capabilities into a near to mid-term spiral. The GHSG is now performing pre-spiral studies that should help with the details in realistic out year cost estimates. A fundamental paradigm sift in DoD F.M is needed to truly take advantage of SD's opportunities.

Logistics:

Challenge: Sparing ACTD Assets – ACTD assets are "hobby shop" systems that are not normally spared properly for operational fielding, as pre-fielding LSA studies are only predictive. The tendency for most programs is to overestimate reliability and underestimate usage. The Global Hawk fits this mold as well. Because of this, the Global Hawk will continue to provide ad-hoc sparing for the ACTD assets until production assets are on line.

Challenge: Spares Requirements – Each Global Hawk spiral is vastly different, making spares tracking a difficult task. Modularity in the system architecture is one way to avoid this, as it would promote commonality between spirals. This would reduce the number of different spares types between spirals. Another method is to make better LCC decisions up front in the RWG analysis of a requirement's impacts on the overall program price tag.

Challenge: Technical Orders and Training – It is very difficult for the Global Hawk end-user to keep up with the number of tech orders and training changes that come out with each spiral delivery. To combat this problem, the GHSG is executing a number of measures. First, they use electronic tech orders, which help ease the pain somewhat for the already overworked GHSG end-user. Also, the GHSG has added both a dedicated training representative to its in-house team and to the user rep office (ACC/DRH). Finally, they are employing a "train the trainer" approach.

Challenge: Initial Reliability/Maintainability Neglect – Many of the fault isolation tools were not built into the original Global Hawk. This is expected, as it is an emerging concept technology. Thus, Global Hawk is trying to incorporate BITs and items that ease the maintenance burden in Spiral five. Although this will benefit the overall program, fault isolation capability should be added into early program spirals.

Challenge: Retrofit Expense – Global Hawk had not always planned on retrofitting the early spirals to bring them up to the capability of the latest spiral. However, the IPT decided that the increased capability on all the assets was worth the price. Despite a $500-$600 Million bill, they have changed course and are making efforts to upgrade early spirals to operate with the most current version. This is a tall order, and is another reason to call for modularity in the architectural design.

Research Question 2: What are some of the lessons learned from the Global Hawk program's spiral development approach that could be useful to other program managers directing a spiral development program?

1. Be aware of the impacts of concurrency in SD
2. Due to SD's heavy workload and shortened timeframe, staff accordingly and cross train.
3. The systems engineering process must be given time to fully decompose requirements.
4. A SD program manager cannot have too much oversight on software development.
5. A SD program should do pre-spiral studies to ensure planned capability "drops" in future spirals are executable and smart.
6. Technical orders and training problems are exacerbated with SD.
7. Don't forget that an ACTD program is a *concept*, not a production platform.
8. Rigorous requirements control is vital to SD success.
9. Make concerted effort to build robustness into component reliability in early spirals
10. High levels of concurrency make configuration management a tall order.

5.2 RECOMMENDATIONS FOR FURTHER STUDY

The first recommendation for further study is to examine the impacts of SD on TOC. Although it is too early to gain a full understanding of TOC implications, the notion of rapid fielding, concurrent design and production, and increased risk will almost certainly raise procurement costs. In addition, once several programs have fielded weapon systems using spiral development, further research is required on operation and sustainment costs of these weapon systems. We believe that SD will field more configurations of the end-item system than a traditional acquisition program would. Thus, each configuration will need its own support equipment, and have very large logistical footprints. This will probably increase LCC of a SD system

The second and final recommendation for study is to analyze the key MTBF data (actuals) for the Global Hawk ACTD platforms as seen in OEF and OIF. That data and analysis can be used to refine the Global Hawk's supportability plan. Since the Global Hawk is an ACTD platform, built with a hobby-shop mindset, one would expect lower reliability than a production asset. Given that the aircraft has logged thousands of hours in OEF and OIF combat missions, what do the actual MTBF show? How can those data be used to adjust the Global Hawk's long-term supportability plans?

5.3 SUMMARY

This MBA project identified key characteristics necessary to implement spiral development in government acquisitions, and presented lessons learned through a case study of the Global Hawk UAV Program. This paper examined the Global Hawk's spiral development strategies in several key program functional areas. It discussed SD challenges, and benefits with particular attention given to successful tactics and potential pitfalls of using this acquisition approach. Finally, it derived several lessons learned applicable to any DoD program manager.

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